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**ELF Communications System
Ecological Monitoring Program:
Electromagnetic Field Measurements
and Engineering Support -- 1987**

D. P. Haradem
J. R. Gauger
J. E. Zapotosky

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<p>A long-term program for studying possible effects from the operation of the Navy's ELF Communications System is being conducted on biota and ecosystems components in north-western Wisconsin and the Upper Peninsula of Michigan. Sixteen general types of organisms from three major ecosystems in the ELF system area are being examined. Formulation of an ELF Ecological Monitoring Program was completed in early 1982 by the Department of the Navy, and studies were initiated in late summer of the same year. Beginning in 1983 and continuing during 1984, major activities of the program consisted of characterization of critical aspects of each study, collection of data to validate assumptions made in proposals, and selection of study sites. From 1985 through 1987, activities centered on the operation of full-scale studies. This report documents electromagnetic (EM) field measurements at investigator selected study sites from 1982 through 1987. Other engineering support activities are also described. <i>Keywords: program results, electromagnetic radiation</i></p>				
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FOREWORD

This report documents measurements of extremely low frequency (ELF) electromagnetic (EM) fields made in support of the U.S. Navy's ELF Communications System Ecological Monitoring Program from late 1982 through 1987. The report also describes other engineering activities in support of these ecological studies. This work was funded by the Space and Naval Warfare Systems Command, Submarine Communications Project Office, under Contract Numbers N00039-81-C-0357, N00039-84-C-0070, and N00039-88-C-0065, to IIT Research Institute (IITRI). IITRI measurement personnel for 1987 were Messrs. D. P. Haradem, R. G. Drexler, J. R. Gauger, M. J. Pavlat, and Dr. J. E. Zapotosky.

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**ELF COMMUNICATIONS SYSTEM ECOLOGICAL MONITORING PROGRAM:
ELECTROMAGNETIC FIELD MEASUREMENTS AND ENGINEERING SUPPORT--1987**

1. INTRODUCTION

1.1 Ecological Monitoring Program

In 1981, concurrent with its decision to complete construction of an Extremely Low Frequency (ELF) Communications System, the Department of the Navy funded an Ecological Monitoring Program. The purpose of the program is to determine whether long-term exposure to electromagnetic (EM) fields produced by the communications system will result in adverse effects on resident biota or their ecological relationships. Monitoring studies have been performed since 1982 by investigators from five universities located in the Great Lakes region.

Accurate data are needed to evaluate cause-and-effect relationships between EM exposure and biological/ecological end points. As part of the program, IIT Research Institute (IITRI) assists university investigators by providing EM field measurements and other EM engineering support. IITRI support activities include analysis of EM aspects of research protocols; design, fabrication, and installation of special EM exposure equipment; and review of EM aspects of investigator reports in the context of environmental protection or risk. Each year, IITRI prepares a report to document its engineering activities performed in support of the program's biological and ecological studies. The present report documents engineering support activities performed during 1987 and provides a comprehensive record of EM measurements from 1982 through 1987.

1.2 ELF Communications System

The complete ELF Communications System consists of two transmitting facilities, one located in the Chequamegon National Forest in Wisconsin and a second located in the Copper Country and Escanaba River State Forests in Michigan (see Figure 1). Each facility consists of long overhead wires (antennas) with buried ground terminals at their ends and a control transmitter building. Both the antenna and grounding elements are located in cleared rights-of-way (ROW). The transmitters broadcast messages using ELF

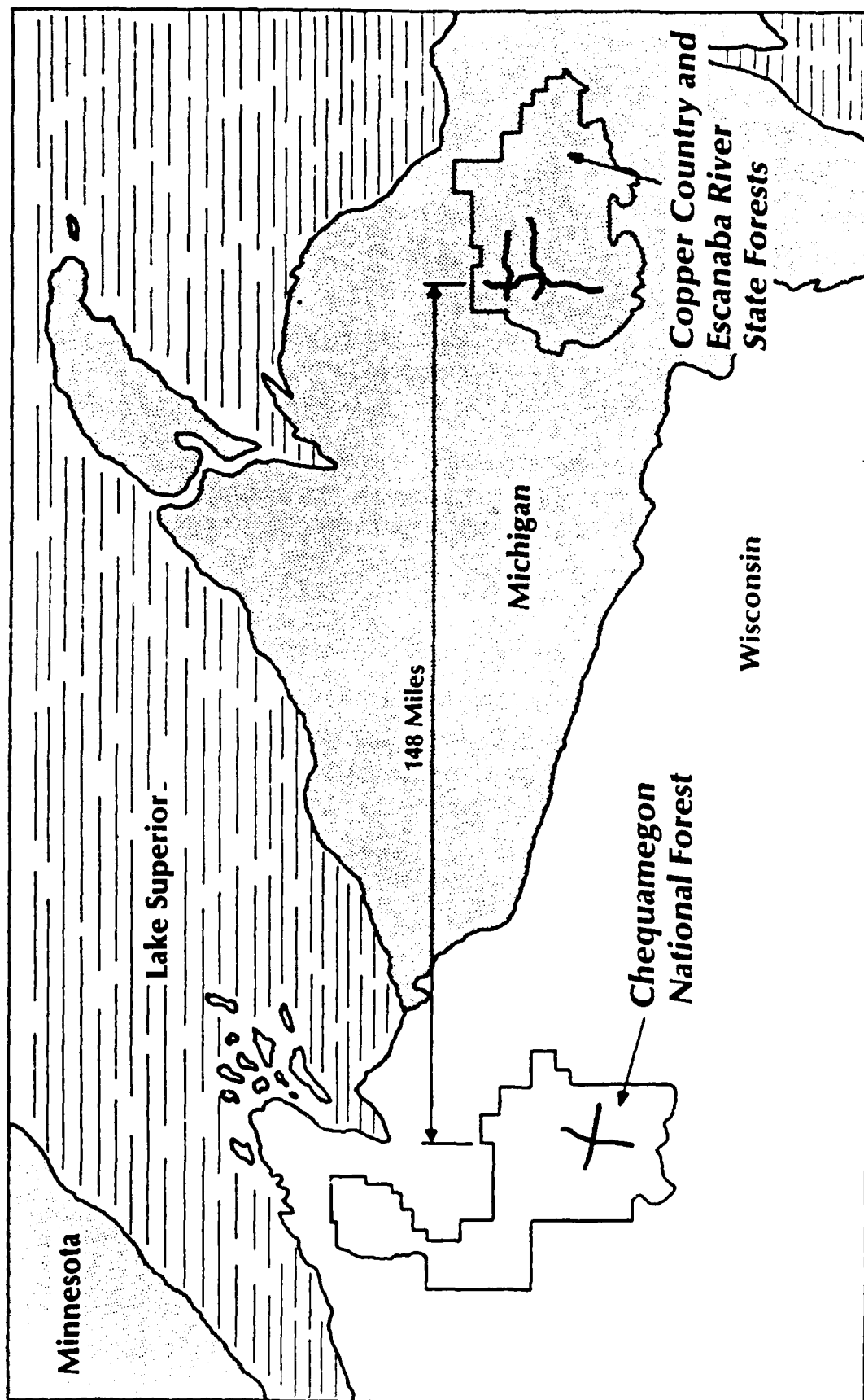


FIGURE 1. ELF COMMUNICATIONS FACILITIES IN WISCONSIN AND MICHIGAN.

EM fields; these fields are the operational component to be evaluated by the Ecological Monitoring Program.

During the construction and testing of the ELF Communications System, EM exposure can be conveniently divided into preoperational, transitional, and operational phases. During the preoperational phase, biota receive no EM exposure from the ELF Communications System. The transitional phase begins with the initiation of system testing; exposures are intermittent and are often at lower intensities than those anticipated from an operational system. When the system achieves full operational capability, EM exposure will be nearly continuous and at full intensity. The Wisconsin Transmitting Facility (WTF) became fully operational during the last quarter of 1985; the Michigan Transmitting Facility (MTF) is expected to become fully operational during the last quarter of 1989.

The EM fields produced by the ELF Communications System are:

- a magnetic field, essentially the same in air and the earth, that is generated by the electrical current in the antenna element
- an electric field in the earth that is the sum of the fields induced by the magnetic field and the current flowing from the buried ground terminals
- an electric field in air that is produced as a result of the difference in potential between the antenna element and the earth

The frequency produced by an operational ELF Communications System is modulated using minimum shift keying (MSK), a special form of frequency shift keying (FSK). An important aspect of MSK modulation is that minimal energy is generated outside the signal bandwidth. The transmitted message is digital. If a zero is to be transmitted, the frequency of the current is 72 Hz; for a one, the frequency is 80 Hz. The center frequency is therefore 76 Hz. The planned frequency for routine operation of the ELF Communications System is centered at 76 Hz; however, the system can also transmit at other frequencies in the 40-48 Hz or 72-80 Hz ranges.

In their assessments, investigators must consider such EM variables as exposure intensity and duration and the frequency of exposure as well as other EM fields (e.g., harmonic frequencies) that may act as synergists. Commercial power transmission and distribution lines also generate EM fields of a

frequency (unmodulated 60 Hz) and intensity similar to those produced by the ELF Communications System. Hence a complex of variables, particularly those related to power distribution, has been considered in characterizing the EM environment at study sites.

1.3 Paired Site Concept

The Ecological Monitoring Program employs a paired test (or ELF EM treatment) and control site design to examine for possible effects of ELF EM fields on biological and ecological variables. This spatial design pairs potentially impacted (test) sites with nonimpacted (control) sites to assess for effects. The test sites are positioned within the zone of potential ELF Communications System influence, while control sites are positioned outside the zone. As in classical experimental design, the control site is used to measure the environmental (ambient) conditions, while the treatment site measures the environmental conditions plus any effects of the EM fields produced by the ELF Communications System. Such paired sites have essentially matched biotic and abiotic characteristics, but purposely dissimilar ELF EM exposures.

Because the EM intensity and operational characteristics required to produce a bioeffect are not known, EM exposure criteria were established as guidelines to assist investigators in selecting study sites. These exposure criteria ensure that the 76 Hz EM fields at a test site are significantly larger than both the 76 Hz EM fields at the control site and the 60 Hz fields at test and control sites. The exposure criteria also ensure that there is not a substantial difference in the ambient 60 Hz EM fields between the test and control sites.

The EM exposure criteria used in site selection are expressed in equation form as follows:

$$T (76 \text{ Hz}) / C (76 \text{ Hz}) > 10 \quad (1)$$

$$T (76 \text{ Hz}) / T (60 \text{ Hz}) > 10 \quad (2)$$

$$T (76 \text{ Hz}) / C (60 \text{ Hz}) > 10 \quad (3)$$

$$0.1 < T (60 \text{ Hz}) / C (60 \text{ Hz}) < 10 \quad (4)$$

where T (76 Hz) = test site exposure due to ELF Communications System
T (60 Hz) = test site exposure due to power lines
C (76 Hz) = control site exposure due to ELF Communications System
C (60 Hz) = control site exposure due to power lines

In Michigan, temporal comparisons of biotic variables will be made between the preoperational and operational phases of the ELF Communications System. Spatial comparisons between test and control sites will also be made. Comparisons planned for Wisconsin are spatial only, since the transmitter there has been operating in various modes since 1969 and a preoperational data base does not exist.

Test and control site selection was completed according to the above criteria in Wisconsin and Michigan prior to 1987. In Wisconsin, field work for the slime mold and wetlands studies was completed in 1987. Only the bird species and communities study remains active in Wisconsin for 1988. The study investigators in Michigan have collected their preoperational data and are moving toward the operational phase of their studies as the MTF test currents are increased and operation becomes more frequent.

1.4 Annual Measurements

IITRI performs an annual survey to document the spatial and temporal aspects of EM fields at each study site. Spatial measurements are important in characterizing the EM exposure at study sites that are extensive in area or at sites where there are large EM field gradients. Temporal comparisons of 60 Hz and 76 Hz fields are also required in order to record changes in EM exposure at study sites from year to year. Ambient 60 Hz fields may change due to construction of new power lines, local changes in the distribution system, and the presence of the ELF antenna, which has been shown to couple 60 Hz currents from power lines. The 76 Hz EM field intensities produced by the ELF Communications System in Wisconsin near ground terminals changed as the ground elements were upgraded to operational status. In Michigan, the 76 Hz EM fields changed from 1986 to 1987 as the MTF began testing with higher currents. Changes in the MTF configuration in 1987 such as the operation of the two east-west elements in parallel, and a change in the grounding condition of unenergized antenna elements, also contributed to differences in the

EM fields between 1986 and 1987. A more comprehensive discussion of these changes appears in Section 3.5.2.3.

Other EM aspects examined during the annual surveys have included measurement of 60 and 76 Hz harmonics, EM field levels produced at Michigan study sites due to operation of the WTF, and EM field values as a function of the phase angle between antenna legs. The former two aspects were examined and found to be below detection levels or so low that they are not considered a problem. The effects of the antenna phase angle on EM exposures at WTF study sites are treated in Appendix K. Because antenna elements at the MTF have not yet operated simultaneously, it has not been possible to determine the effects of the antenna phase angle on EM exposure at Michigan study sites. These will be determined after the MTF begins simultaneous, phased operation of the antenna elements.

1.5 Other Support

In order to accommodate fleet operations, the testing of new hardware, and the testing of utility interference mitigation, the transmitting facilities operate at numerous frequency, modulation, and power conditions during their transitional operating phase. IITRI maintains a data base of the WTF and MTF operation log data received from the Navy and provides investigators with a summary of the operating hours and modes of the antennas (see Section 4) This summary may be used by investigators in conjunction with measured values at the study sites to construct exposure regimes for correlation with measured biological and ecological end points.

Two ecological studies use buried culture cells that isolate study organisms from the surrounding soil. IITRI personnel reviewed the proposed design of the culture cells in 1983. Two areas of concern were the matching of internal to external EM fields and the measurement of internal EM fields. IITRI subsequently helped to design, fabricate, and install culture cell exposure chambers and control apparatus to address the field-matching problem. Protocols for the setup and measurement of EM fields within the cells were provided to investigators.

Culture cell chambers for slime mold studies were established in 1984. Exposure control apparatus were added in 1985 and used through 1987, the last field year for the slime mold studies.

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In 1987, IITRI designed and fabricated microprocessor-controlled data loggers (see Figure 2). Three of these units were installed at the slime mold culture cells in Wisconsin. The data loggers were programmed to measure the voltage and current of the culture cell, as well as the chamber temperature, on an hourly basis. These data were stored in memory and then retrieved by IITRI personnel every two weeks. Once retrieved, the data were used to calculate the electric fields and current densities in the culture cells. Calculated values of the culture cell fields from the logger data have been provided to the investigator.

The electrical measurements made by the data logger are the same measurements that previously had been made annually by IITRI and weekly by the investigator. The data loggers were used in order to more closely monitor the study chambers for variations in the electric field and current density that may result from factors such as rainfall, temperature, or changes in conductivity of the culture cell medium as the slime mold multiplies. The data loggers were kept at the field study sites from July to mid-October, when the field season ended and the culture chambers were removed.

The data loggers, which are battery operated and program controlled, may be modified for use in many field applications. Their usefulness in each of the other ecological studies is currently under consideration.

Culture cell sites for the soil amoeba study were established in Wisconsin in 1986 and apparatus was put in place in order to perform preliminary experiments prior to integrating this technique at Michigan study sites. In 1987, collector electrodes were installed at the Michigan soil amoeba study sites, and culture chambers were used for preoperational studies of amoeba growth rates. IITRI personnel measured open circuit voltages on the collector electrodes to ensure their integrity. Problems that arose due to corrosion of the solder joints between the culture cell electrodes and lead wires were resolved by insulating the joint with sealant. Welded joints will be used in the future.



FIGURE 2. MICROPROCESSOR-CONTROLLED FIELD DATA LOGGER.

IITRI also provided special assistance to the upland flora and soil microflora studies, which use extensive ambient monitoring systems for their study sites. Analyses were conducted to estimate the magnitudes of ELF voltages that would be induced on cabling and equipment, the impact of these voltages on personnel safety, and possible system interference. Field measurements of these voltages were also made at low-power antenna operation to verify the analyses.

2. ECOLOGICAL MONITORING STUDY SITES

2.1 Summary of Site Status

Selection of test and control sites in both Wisconsin and Michigan began in 1983 under the criteria described in Section 1.3. In Wisconsin, actual measurements of 60 Hz and 76 Hz EM fields were used to check adherence of the candidate sites to the established criteria. Because sites in Michigan were chosen prior to the completion of the MTF antenna, they were based on measurements of 60 Hz fields and preoperational estimates of the 76 Hz EM fields that were calculated using engineering models of the MTF ELF Communications System. The MTF antenna was completed in 1986 and 76 Hz measurements were then possible for the first time. Measurements made in 1986 were used to verify the acceptability of the test and control sites selected prior to the completion of the antenna. All test and control sites were confirmed to be acceptable or conditionally acceptable. (These terms are defined in Appendix J.) The animal holding facility at the small mammals and nesting birds laboratory, however, was found to have undesirably high 60 Hz EM fields. In 1987, the same was found to be true of red maple leaf and pine needle sample collection points for the upland flora and soil microflora studies. Action taken with regard to these sites is discussed below.

Special sites such as the animal holding facility and the red maple and pine needle collection points have a commonality to the test and control sites. That is, all test and control animals to be tested at the small mammals and nesting birds laboratory reside temporarily in the animal holding facility. Similarly, the red maple leaves and pine needles gathered at collection points are distributed at both test and control sites for decomposition studies. It is therefore not accurate to label these special sites as either test or control sites. However, so as not to confound the test or control site exposures, it is logical to use the EM exposure criteria of a control site as a standard for these special sites.

According to this standard, the laboratory testing site for the small mammals and nesting birds studies (1L1) did not meet all site criteria. At this site, the 60 Hz magnetic fields at the animal holding facility are 10 to 100 times higher than the 60 Hz magnetic fields at treatment and control trapping sites, respectively. Exposure to comparable or higher ELF magnetic

intensities at the holding facility may result in the masking of differences between animals trapped at treatment and control sites.

An alternate location was chosen for the animal holding facility that is only three miles from the Crystal Falls laboratory so as to minimize stress on the animals during transport from the holding facility to the laboratory. IITRI field crews made EM measurements at this alternate location and found the 60 Hz magnetic fields to be of the same order of magnitude as those measured at control sites.

New measurement sites were established in Michigan in 1987 for the upland flora and soil microflora studies. These new sites are at collection points for red maple leaves, oak leaves, and pine needles (site numbers 4S1-1, 4S2-1, and 4S3-1, respectively). All 76 Hz fields satisfied the defined criteria for these sites, but the 60 Hz magnetic flux density at the red maple leaf and pine needle collection points was typically an order of magnitude greater than that measured at study sites. Relocation of these sites is under consideration.

2.2 Summary of Site Locations

Figure 3 shows the locations of field sites for the Wisconsin studies relative to the WTF antenna. The three studies for which EM field measurements were made are identified in the upper left-hand corner of the figure. The black dots represent the locations of field sites at which IITRI field crews evaluated the ELF EM fields. No new sites were established in Wisconsin in 1987.

Figure 4 shows the locations of field sites for the Michigan studies relative to the MTF antenna. The seven studies for which EM field measurements were made are identified in the upper left-hand corner of the figure. The black dots represent the locations of field sites at which IITRI field crews evaluated the ELF EM fields.

The red maple leaf and pine needle collection sites do not appear in Figure 4. These two sites are in Houghton County, which is beyond the range of the map shown.

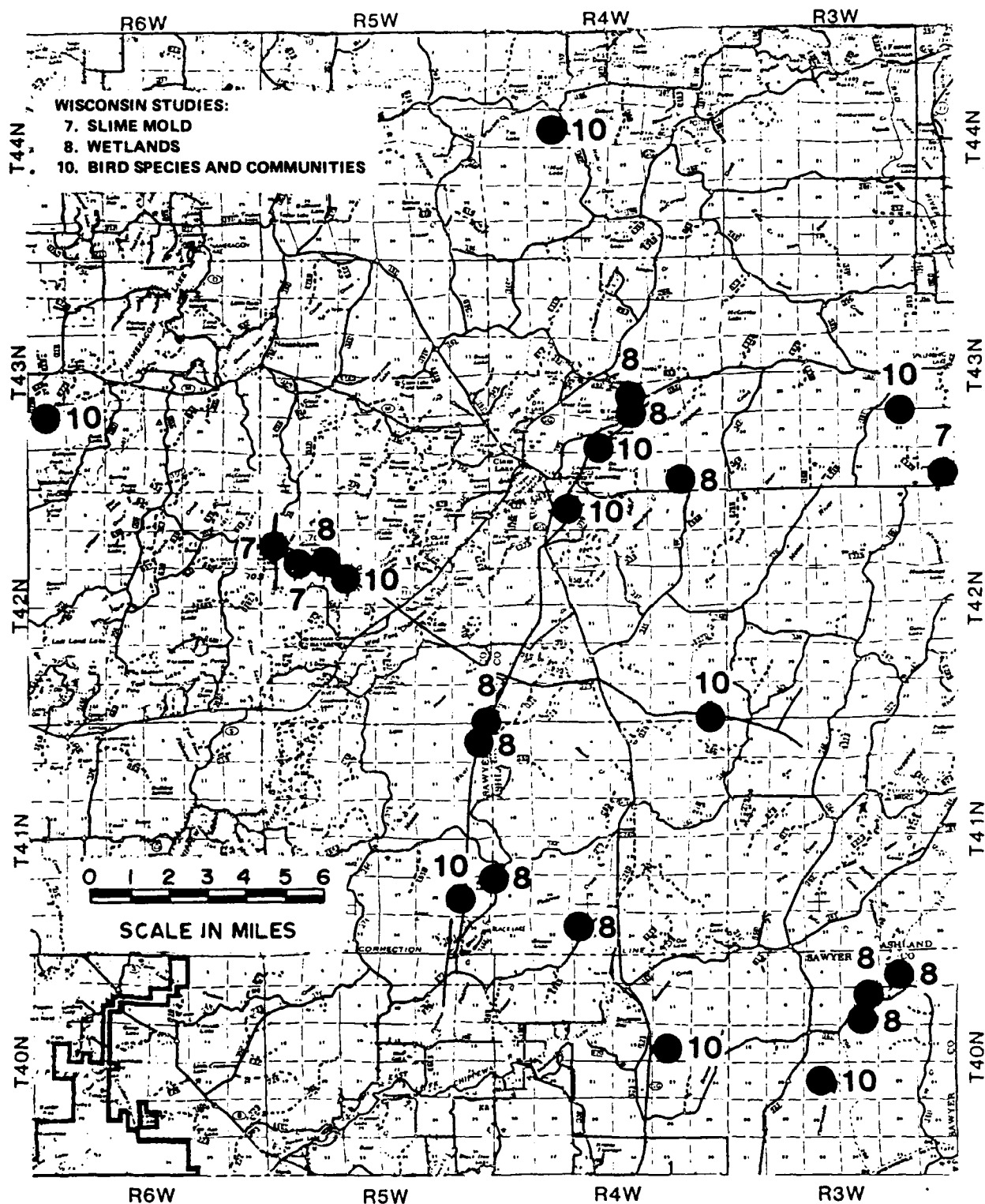


FIGURE 3. FIELD SITES FOR WISCONSIN ECOLOGY STUDIES.

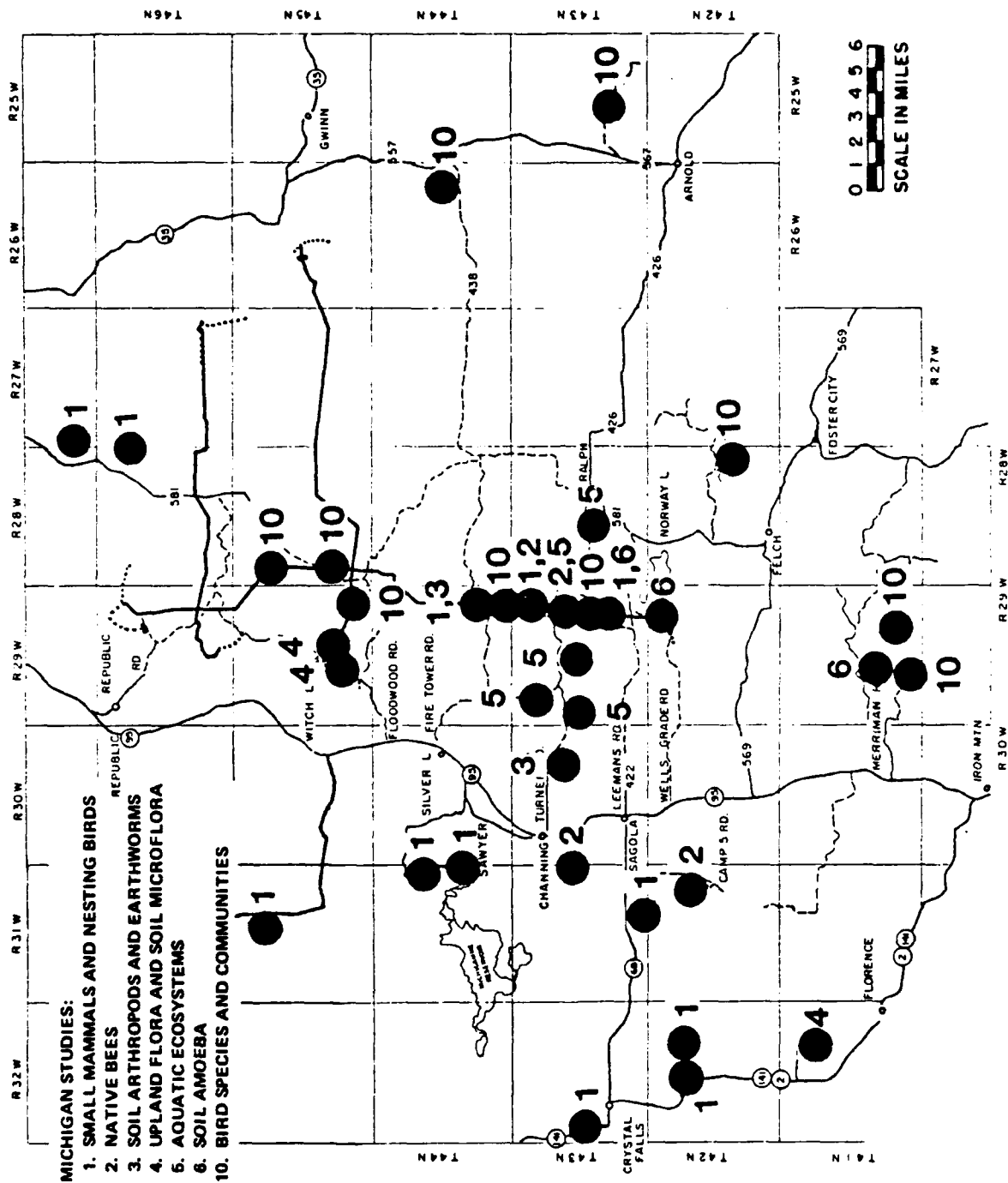


FIGURE 4. FIELD SITES FOR MICHIGAN ECOLOGY STUDIES.

3. EM FIELD MEASUREMENTS AND SUPPORT

3.1 EM Field Description

The three EM fields under investigation in this program are the magnetic field, longitudinal electric field, and transverse electric field.

A magnetic field is generated by current passing through a conductor. The ELF Communications System and power lines produce consistent and predictable magnetic fields that are generally unaffected by the physical environment such as vegetation, soil, and nonmetallic structures. Magnetic fields are unchanged at medium boundaries such as air/earth or air/water. Thus, magnetic field measurement techniques need not consider field shielding, enhancements, or perturbations from the local environment. This local uniformity of the magnetic field allows repeatable measurements over time, even over a number of years, provided that the field source remains constant.

The longitudinal electric field in the earth is measured as a difference in potential at the surface of the earth. The two sources of longitudinal electric field associated with the ELF Communications System are (1) that induced by the magnetic field and (2) that generated by the ground terminal currents. Longitudinal electric fields produced by power lines are generated by the lines' magnetic fields and by unbalanced currents flowing in the earth. The uniformity of longitudinal electric fields is affected by local soil conductivities and other anomalies such as large rocks, tree roots, and pools of water. Overall, however, soil conductivity is rather uniform. Thus, longitudinal electric field measurements are fairly uniform and repeatable when anomalies are avoided. Some year-to-year variations may occur because of changes in soil moisture content, which affect soil conductivity.

The transverse electric field in the air is generated as a result of the operating voltage of the ELF antenna with respect to ground or as a by-product of the longitudinal electric field. Power lines generate a transverse electric field in a similar manner. The operating voltage of the overhead antenna wire (or power line) with respect to the earth's surface sets up a vertical (transverse) electric field. This vertical field is limited to the ROW and other nearby cleared areas. Trees, vegetation, and other conductive objects act as a shield.

A difference in potential between two grounded objects such as trees can be set up by the longitudinal electric field. This difference in potential in turn generates a horizontal electric field in the air. The horizontal and vertical fields are perturbed by vegetation, people, and instrumentation, all of which are more conductive than air. The perturbations of the field may take the form of an enhancing of the ambient field near objects or a shielding effect on the surroundings. This results in a high variability of the transverse electric field over a small area. The transverse electric field is measured in open areas in an effort to obtain a typical unperturbed measurement.

3.2 Field Probes and Measurement Equipment

The magnetic flux density, transverse electric field intensity, and longitudinal electric field intensity are measured using directional field probes designed and calibrated by IITRI. Each of these probes, when placed in the existing electric or magnetic field, outputs a voltage proportional to the field intensity. The value of the applied field can be obtained by means of individual sets of calibration factors for each probe.

The magnetic field probe is composed of a multiturned coil of wire wound on a ferrite core and shunted by appropriately chosen resistors to obtain a flat frequency response. The probe outputs a voltage proportional to the magnetic flux density parallel to the axis of the core. The voltage is converted to the magnetic flux density by means of a calibration factor determined prior to each field outing. Two of the magnetic field probes are shown in Figure 5.

The transverse electric field probe consists of a spherical sensor/transmitter, a fiber-optic data link, and a receiver. The probe outputs a voltage proportional to the transverse electric field along the primary axis of the spherical sensor/transmitter. The voltage is converted to the electric field intensity by means of a calibration factor determined prior to each field outing. The calibration factor and probe operation are periodically checked using a portable electric field probe calibrator. The transverse electric field probe is shown in Figure 6.

The longitudinal electric field probe consists of three electrodes mounted on a fiberglass frame so as to form two orthogonal 1-m-spaced

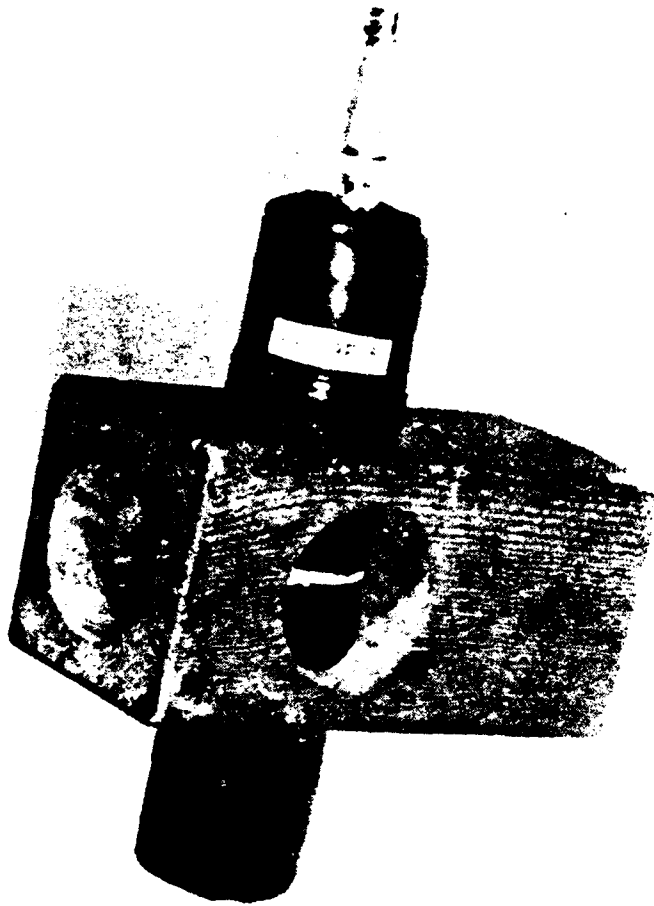


FIGURE 5. MAGNETIC FIELD PROBES.

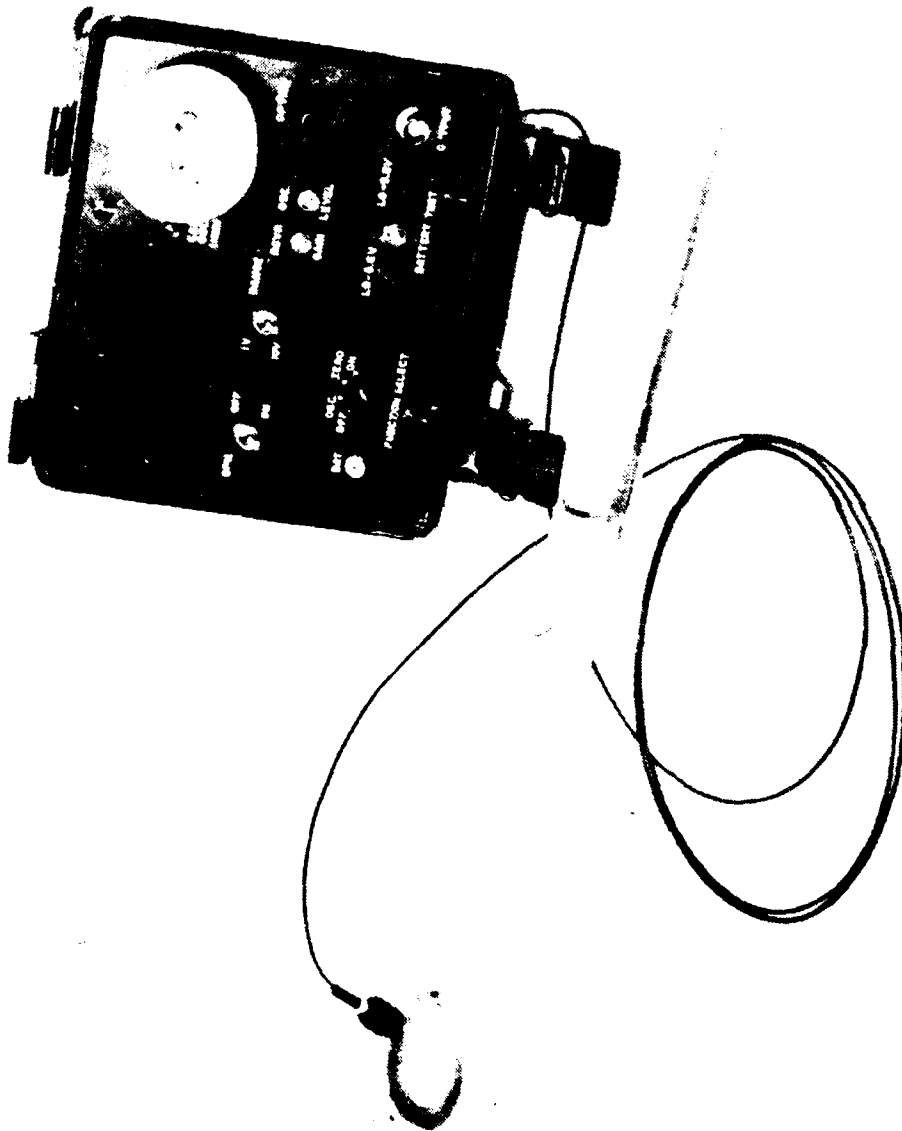


FIGURE 6. TRANSVERSE ELECTRIC FIELD PROBE.

electrode pairs. The electrodes are pushed into the earth, and a switch connects a voltmeter across one pair of electrodes at a time. The voltage measured across each pair of electrodes is equal to the longitudinal electric field in the given direction. The probe is shown in Figure 7. Note that a compass and a cradle are mounted atop a 1-m vertical stalk that is hinged at the juncture of the probe legs.

The compass aids in alignment of the probe legs prior to raising the stalk. The cradle is designed to hold the magnetic field probe in three orthogonal positions at a 1-m height and orient the probe precisely with the legs of the longitudinal electric field probe.

IITRI has developed a computer-driven system for calibrating electric and magnetic field probes over their usable frequency range (see Figure 8). At the heart of the system are:

- a Hewlett-Packard 86B computer equipped with an IEEE 488 instrument interface bus
- a Hewlett-Packard 3421A data acquisition unit
- a Valhalla 2703 precision ac calibrator

The system generates a uniform electric field between a pair of 1-m-square, 1/3-m-spaced parallel plates with guard rings. A uniform magnetic field is produced over a large volume by a set of 1-m-radius Helmholtz coils. The calibration system produces a table of each probe's calibration factors and a plot of the probe's output voltage as a function of frequency. The transverse electric field probe and magnetic field probe are calibrated before and after each use, and records are kept of past calibrations.

The electrical stability of the transverse electric field probe is better than $\pm 5\%$ over a one-year period. Portable electric field calibration plates are used during field measurements so that the probe operation can be verified periodically. The electrical stability of the magnetic field probe is better than $\pm 1\%$ over a one-year period. The probe is constructed solely of passive components, making routine calibration checks during field measurements unnecessary. The longitudinal electric field probe, which consists solely of a perpendicular pair of 1-m-spaced electrodes, requires no calibration. The electrical stability of this probe is excellent.

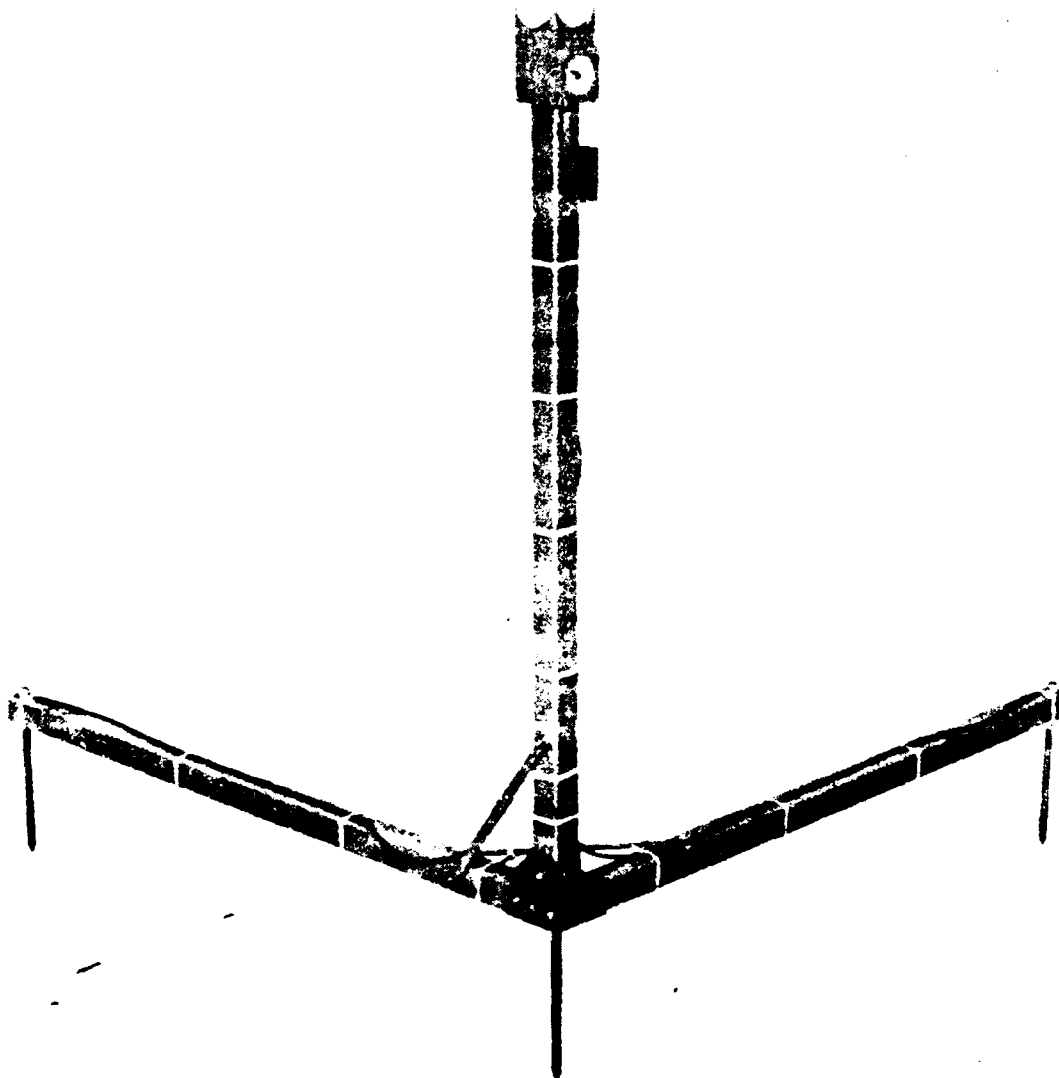


FIGURE 7. LONGITUDINAL ELECTRIC FIELD PROBE.

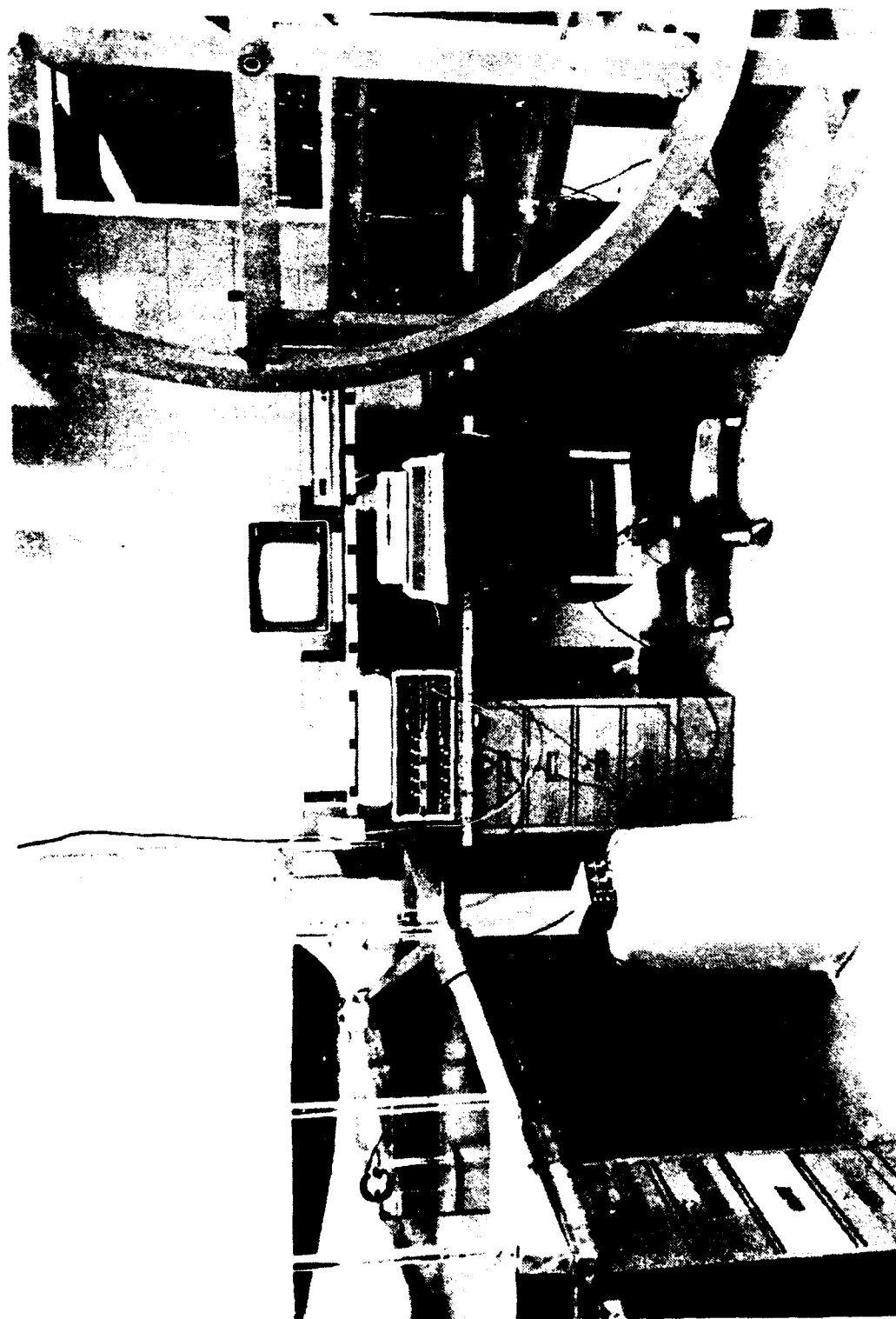


FIGURE 8. COMPUTER-DRIVEN ELECTRIC AND MAGNETIC FIELD PROBE CALIBRATION SYSTEM.

The meter used to measure the output voltages of the probes is a Hewlett-Packard 3581A signal wave analyzer. The HP 3581A functions as a frequency selective rms-calibrated voltmeter with factory modifications for battery and 1 Hz bandwidth operation. A 3 Hz bandwidth is used to measure 60 Hz and unmodulated ELF signals, but a wider bandwidth is needed to measure modulated ELF signals. Because the wider bandwidth will include 60 Hz signals produced by power lines, an IITRI-fabricated active notch filter is placed in series with the wave analyzer when the 60 Hz and ELF signals are of similar magnitudes in order to remove the 60 Hz signals and their harmonics.

3.3 Measurement Techniques

The magnitude of EM fields is determined by the measurement of orthogonal field components. This requires field measurements along three orthogonal axes. For simplicity and repeatability, the axes chosen are the north-south, the east-west, and the vertical. The longitudinal electric field intensity (electric field measured in the earth) has no vertical component; therefore, only the north-south and east-west directional components are measured. In the case of the transverse electric field and the magnetic flux density, all three orthogonal field components are measured. The orthogonal measurements are then used to compute a vector sum or maximum. A drawback to this method is that it yields the correct field maximum only when a single field source is present or dominates. When more than one field source is present, the computed vector sum will be conservative; that is, it will be greater than or equal to the actual maximum.

The following summarizes the technique of orthogonal field measurement:

- (1) The magnetic field probe and transverse electric field probe are used to measure three orthogonal components using a compass bearing and the plane of the earth's surface as references. The magnetic field and the transverse electric field are measured in north-south, east-west, and vertical orientations.
- (2) The longitudinal electric field is of interest near the surface of the earth, where it will come in contact with biota under study, and has no vertical component. Therefore, only the north-south and east-west orientations are measured.

A geometric presentation of the measurement and summation of orthogonal components is shown in Figure 9. The figure presents the two-dimensional longitudinal electric field geometry and the three-dimensional magnetic field and transverse electric field geometry. The resultant, R, in each case is the vector sum of the individual orthogonal components and is the value reported in data tables.

3.4 Measurement Protocols

3.4.1 Wisconsin Protocol

The WTF was built in the late 1960s to be used as a test facility for ELF communications. It transmitted intermittently from the time of its initial construction until upgrades were made in 1985, after which it transmitted on a full-time basis.

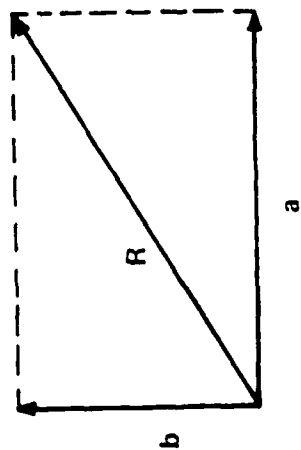
Before 1985, the WTF operated at numerous frequency, modulation, and intensity conditions with either the north-south, the east-west, or both antenna elements being powered. During this period, the antenna was generally under local control, and specific conditions of antenna current, modulation, frequency, and phase angle could be requested for measurements and testing.

In 1985, the WTF was upgraded to a fully operational system with the installation of new transmitters early in the year. The transmitters required testing in mid-year, which allowed only limited manipulation of antenna conditions. This was followed by full-time transmitting during the fourth quarter, which did not allow any control over antenna conditions. The antenna continued full-time transmitting through 1986 and 1987.

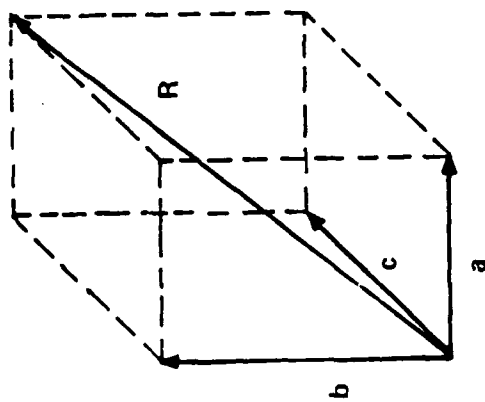
IITRI required control of the WTF antenna for the measurement protocol used prior to 1985; the loss of antenna control therefore required that a new protocol be adopted. The following subsections describe the pre-1985 protocol and the protocol used from 1985 onward.

3.4.1.1 Pre-1985 WTF Protocol

Prior to June 1985, the EM measurement protocol in Wisconsin consisted of making orthogonal sets of measurements of the transverse electric field, longitudinal electric field, and magnetic flux density at each measurement point as follows:



$$R = \sqrt{a^2 + b^2}$$



$$R = \sqrt{a^2 + b^2 + c^2}$$

FIGURE 9. GEOMETRIC PRESENTATION OF THE VECTOR SUM OF ORTHOGONAL MEASUREMENT COMPONENTS.

- (1) measurement of the ambient 60 Hz fields with both antenna elements off
- (2) measurement of unmodulated 76 Hz fields from the north-south antenna element with the east-west antenna element off
- (3) measurement of unmodulated 76 Hz fields from the east-west antenna element with the north-south antenna element off

All measurements were made using a narrow bandwidth meter setting to discriminate the frequency of interest. When necessary, the 76 Hz fields at the WTF measured at lower currents were extrapolated to 300 amperes (full power). Each set of orthogonal components was used to compute a vector sum, or field magnitude. The 76 Hz field magnitudes from the north-south and east-west antenna elements were then added algebraically to compute the worst-case or highest field level that could be produced by both antennas operating simultaneously at any phase angle. These worst-case values were presented in pre-1985 reports.

3.4.1.2 WTF Protocol from 1985 Onward

In 1985, the WTF measurement protocol was modified so that measurements could be made during continuous, phased operation of the two antenna elements. The new protocol, adopted in 1985, was used again in 1986 and 1987 and is outlined below:

- (1) The EM fields generated by the ELF Communications System, which are normally modulated with a center frequency of 76 Hz, are measured with a meter bandwidth setting of 30 Hz to accommodate the wider frequency spectrum of the modulated signal.
- (2) At control and/or other sites where the 60 Hz ambient fields are comparable to the ELF fields, an IITRI-fabricated active notch filter instrument is used to eliminate the 60 Hz signal from the field measurement.
- (3) At each site, the orthogonal components of the magnetic flux density and transverse and longitudinal electric fields are measured, and a vector sum magnitude is computed for each field. The antenna current phase angle is recorded (normally -75° for Wisconsin).
- (4) For the six sites where phasing data have been obtained, the longitudinal electric field magnitudes obtained in Step 3 are multiplied by the correction factor from Appendix K to obtain the actual field magnitude.

- (5) The 60 Hz ambient fields are unmeasurable unless the ELF transmitter can be turned off (unlikely during fleet transmission), or unless the ambient 60 Hz levels are higher than the ELF-signal-generated "noise" at the same frequency. This latter scenario is likely only at certain control sites. When 60 Hz fields are measured, a narrow bandwidth meter setting is used.

This protocol allows for direct comparisons between pre- and post-1985 data for all but six sites. These six sites--8A2, 8M3, 8M4, 10T6-2, 10T8-4, and 10T10-1--are near enough to both WTF antennas that their EM fields vary with the phasing of the antennas. Appendix K contains tables of conversion factors for these sites that allow comparisons of EM field measurements made in any year at any antenna phasing.

3.4.2 Michigan Protocol

Construction of the MTF began in 1984 and continued through 1985. During this period the MTF was not capable of generating ELF EM fields.

Construction of the MTF was completed in early 1986, and intermittent operation began at low power levels (4-10 ampere antenna current) with only one antenna element operating at a time.

3.4.2.1 1986 Protocol

The EM measurement protocol in Michigan in 1986 consisted of making orthogonal sets of measurements of the transverse electric field, longitudinal electric field, and magnetic flux density at each measurement point as follows:

- (1) measurement of the ambient 60 Hz fields with all three antenna elements (north-south, northern east-west, and southern east-west) off
- (2) measurement of the unmodulated 76 Hz fields from the north-south antenna element with both east-west antenna elements off
- (3) measurement of the unmodulated 76 Hz fields from the northern east-west antenna element with the other antenna elements off
- (4) measurement of the unmodulated 76 Hz fields from the southern east-west antenna element with the other antenna elements off

The MTF continued to operate intermittently at low levels (15 ampere antenna current) in 1987, but under an antenna configuration that was slightly different from the one used in 1986. In 1987, the north-south antenna element was operated alone as in 1986; the northern east-west and southern east-west antenna elements, however, were operated simultaneously and in phase with each other in 1987 rather than individually as in 1986. The northern east-west and southern east-west antenna elements will continue to be operated in parallel during testing and in the final operating configuration. The two east-west elements configured in this parallel fashion will be collectively referred to as the east-west element in this report and future documentation.

3.4.2.2 1987 Protocol

The EM measurement protocol for Michigan changed only slightly in 1987 to account for the new operating configuration. It consisted of making orthogonal sets of measurements of the transverse electric field, longitudinal electric field, and magnetic flux density as follows:

- (1) measurement of the ambient 60 Hz fields with all three antenna elements (north-south, northern east-west, and southern east-west) off
- (2) measurement of the unmodulated 76 Hz fields from the north-south antenna element with both east-west antenna elements off
- (3) measurement of the unmodulated 76 Hz fields from the northern east-west and southern east-west antenna elements operated in parallel with the north-south antenna element off

All measurements in 1986 and 1987 were taken using a 3 Hz bandwidth meter setting to discriminate the frequency of interest. Each set of orthogonal measurements was used to compute a vector sum, or field magnitude, corresponding to that measurement condition. The 76 Hz magnitudes were also linearly extrapolated to full antenna power (150 amperes). The extrapolated magnitudes contributed by the individual antenna elements were then algebraically summed to give the worst-case, or highest, field level that could be produced by all antenna elements operating simultaneously at any phase angle.

3.5 1987 Measurements and Data Summary

The annual EM field measurements in Wisconsin were conducted by IITRI field crews during the week of 17 to 22 August 1987. Those in Michigan were conducted during the period from 22 September to 8 October 1987. All active sites were measured during these periods.

Table 1 presents a summary of the number of sites and corresponding measurement locations for 1987. As shown, a total of 266 measurement points were needed to characterize 74 sites. The number of measurement locations per site was determined by plot size, the presence of known or anticipated EM field gradients, and the information needed by the study investigators for statistical analysis.

TABLE 1. SUMMARY OF 1987 EM FIELD MEASUREMENT LOCATIONS

Study	Number of Measurement Sites			Number of Measurement Points		
	Pre-Existing, Still in Use	New, 1987	Total	Pre-Existing, Still in Use	New, 1987	Total
Small Mammals and Nesting Birds	13	2	15	41	23	64
Native Bees	4	0	4	13	2	15
Soil Arthropods and Earthworms	2	0	2	8	0	8
Upland Flora and Soil Microflora	3	3	6	29	3	32
Aquatic Ecosystems	10	0	10	17	0	17
Soil Amoeba	3	0	3	9	0	9
Slime Mold	3	0	3	9	0	9
Wetlands	11	0	11	66	0	66
Bird Species and Communities						
Michigan	10	0	10	24	0	24
Wisconsin	<u>10</u>	<u>0</u>	<u>10</u>	<u>21</u>	<u>1</u>	<u>22</u>
Total	69	5	74	237	29	266

3.5.1 Wisconsin Measurements

The 1987 annual EM survey in Wisconsin consisted of EM field magnitudes measured during simultaneous operation of both antennas at an antenna current phase angle of -75° . Measurements were made during periods of modulated signal transmission with a center frequency of 76 Hz and a current of 300 amperes.

The data taken during the 1987 annual EM measurements in Wisconsin appear in Appendixes G, H, and I. No 60 Hz data were taken in 1986 or 1987, when IITRI measurement crews did not have control of antenna conditions. In these appendixes, 76 Hz data for years prior to 1985 are presented individually for each antenna element (north-south and east-west). These data are readily compared to data from the new protocol by calculating the algebraic sum of the fields produced during individual operation of the north-south (NS) and east-west (EW) antenna elements, and comparing them with the EM fields measured in later years during the simultaneous operation of both antenna elements. The 1985-1987 76 Hz data are presented in columns labeled "Both, -75° ," indicating that both antenna elements were operating at a current phase angle of -75° . For some sites, 1985 data are also given in the "NS" and "EW" columns. These data were taken early that year during site selection/relocation activities, during the phasing measurements, or when only one antenna element was operational at the time of the measurement.

3.5.2 Michigan Measurements

The data taken during the 1987 annual EM measurements in Michigan appear in Appendixes A through F and Appendix I. Construction of the antenna was completed in 1986, and 76 Hz EM field measurements were possible for the first time that year. 76 Hz measurements were made again in 1987. In both 1986 and 1987, the antenna operated at current levels lower than the anticipated 150 ampere full operating current. In 1986 the primary operating currents were 4 amperes for the NS element, 6 amperes for the northern east-west (NEW) element, and 6 and 10 amperes for the southern east-west (SEW) element. In 1986, 76 Hz measurements were taken at 4, 6, and 6 ampere antenna element currents for the NS, NEW, and SEW elements, respectively. In 1987, the NS and EW elements were operated at 15 amperes and measurements were made at this current for both elements.

Each appendix for the Michigan-based studies contains nine data tables. For each of the three fields measured (the transverse electric field, longitudinal electric field, and magnetic flux density) there are a 60 Hz data table, a 76 Hz data table for measurements at low-power operating currents, and a 76 Hz data table for extrapolations of the measured fields to a full-power condition. These tables are described below.

The tables of 60 Hz data appear first in each appendix. Each table contains separate columns for data from 1983 through 1987. Footnotes for each column describe the physical status of the ELF antenna during the 60 Hz measurements for that year. The physical status of the ELF antenna has a significant impact on the 60 Hz EM fields measured at test sites because it affects the degree of coupling to the antenna of 60 Hz fields generated by nearby power lines. This phenomenon is explained in Section 3.5.2.2.

Following the 60 Hz data tables are tables containing 76 Hz EM field intensities for the antenna currents used in 1986 and 1987. These data represent the actual field intensities to which study biota were exposed.

In the third group of tables, low-power measurement data are linearly extrapolated to a 150 ampere (full-power) current for each antenna element. Extrapolated data are presented for both 1986 and 1987. Extrapolations were not performed when low-power measurements were below the sensitivity of the measurement instruments. The 1987 extrapolations are more accurate predictions of the EM field levels at the full operating antenna current, since they are based on measurement data for antenna currents 2.5 to 4 times greater than those used in 1986. The 1987 extrapolations also reflect the final operating antenna configuration of the two EW antenna elements driven in parallel, as opposed to 1986 when they were driven individually. The worst-case, or maximum, field levels that can occur during simultaneous operation of both antennas at any antenna phasing can be calculated as the algebraic sum of the levels from the individual antenna extrapolations. Similarly, minimums can be calculated as the algebraic difference.

3.5.2.1 Measurement Point Selection

With the advent of 76 Hz EM fields at the Michigan study area in 1986, measurement points were added at most study sites in order to define the spatial variation of the 76 Hz fields over each site. In 1987, this effort

was continued as new measurement transects were established at the Cleveland Homestead, North Turner Road, and Ford River North and South sites of the nesting birds studies. Measurement point locations in 1986 and 1987 were selected on the basis of study plot size and shape and its location relative to the antenna elements.

Control sites, all of which are several miles from the nearest antenna element, are expected to have minimal EM field gradients. At small, localized control sites, a single measurement point was deemed sufficient to characterize the fields. Intermediate-size rectangular control sites were measured at the points nearest to and farthest from the antenna grid. Large control sites were measured at several points as necessary to define the extremities of the study area.

EM field gradients at test sites, however, are expected to be large for all but the smallest of sites. It was generally necessary to make several measurements at all test sites. The selection of measurement points for the test sites was based on one of four strategies dictated by the nature of the site. For sites comprised of long, narrow transects parallel to the antenna (e.g., the bird species and communities studies), measurements typically were taken at the ends of the transect and often at intermediate points along the transect. For sites of very restricted area (e.g., the aquatic ecosystems studies), only one measurement was made at each experiment location. The final two measurement strategies were applied at test sites covering a large area. For those sites arranged with well defined, grid-like borders, measurements were made at the borders or corners of the plots such that the measurements encompassed the study area. For those sites without distinct borders, measurements were made along a transect perpendicular to the antenna, typically at 25-m intervals.

This measurement point selection technique allows the investigators to estimate the EM field intensity at any point of interest within a study plot. Such estimates can be made based on the fact that the EM fields vary greatly with distance from the antenna but show little variation along a path parallel to it. Therefore, given the distance of a point of interest from the antenna, the EM fields can be estimated by interpolation between measured values at greater and lesser distances from the antenna. Because the fields vary little

along a path parallel to the antenna, the point of interest and measured points do not need to be at the same position along the length of the antenna. The EM field can be estimated by linear interpolation between the two measured points. The accuracy may be improved by plotting the field gradients. This was done for all transects at the nesting birds study sites; the plots appear in Appendix A.

3.5.2.2 Coupling of 60 Hz Fields

The 60 Hz data tables for Michigan studies, in Appendixes A through F and Appendix I, show that there were significant yearly fluctuations of the 60 Hz EM fields from 1983 through 1987. The primary factors in these fluctuations were:

- completion of antenna installations in 1986
- parallel connection of the two EW antenna elements in 1987
- differences in antenna-power amplifier connections between 1986 and 1987
- changes in power line loads
- changes in earth conductivity

The first three factors apply only to test sites; the last two apply to test and control sites.

The 60 Hz EM fields at the test sites are strongly influenced by the presence of the ELF antenna elements. This is because EM fields generated by 60 Hz power lines couple to the conducting loop formed by the ELF antenna, its ground terminals, and the earth. This coupling results in a 60 Hz current flow on the antenna wires that in turn sets up new 60 Hz EM fields in nearby areas. The 60 Hz EM fields generated by the two sources (power lines and antenna) may interact at test measurement sites and elsewhere. The general observation has been that the longitudinal electric fields sourced by the power lines and antenna partially cancel each other, leaving a 60 Hz field that is lower in magnitude than the field measured prior to antenna construction. The magnetic fields from power lines decay more rapidly than the longitudinal electric fields, and they do not appear to significantly interact with the 60 Hz magnetic fields from the antenna. The result is 60 Hz magnetic fields near the antenna that are greater in magnitude than those measured prior to antenna construction.

The coupling of ambient 60 Hz fields to the ELF antenna was first observed in 1986, coincident with the completion of antenna construction in Michigan, and was verified in 1987. This phenomenon will continue as long as the ELF antenna and power lines are present. Differences in the 60 Hz EM fields at test sites between 1986 and 1987 are likely due to changes in coupling to the antenna elements resulting from changes in antenna configuration. These antenna changes were the parallel connection of the two EW antenna elements and differences in the antenna connections to the power amplifiers in the antenna "off" mode when the 60 Hz measurements were made.

Variations in the 60 Hz EM fields at control sites are not related to the existence of the ELF antenna or its topology. These changes are most likely the result of varying power line load currents and/or local changes in earth conductivity. These factors may also influence the 60 Hz fields at test sites.

3.5.2.3 76 Hz EM Fields

Measurement of the 76 Hz EM fields was possible for the first time in Michigan in 1986 upon completion of the ELF antenna. In 1987, these fields were remeasured under antenna operating conditions that were somewhat different from those in 1986. The differences are pertinent in comparing the 76 Hz EM field measurements for 1986 and 1987, and are summarized in Table 2.

TABLE 2. 76 HZ EM FIELD MEASUREMENT
ANTENNA OPERATING CONDITIONS

Antenna Condition	1986	1987
Antenna Elements Measured	NS NEW SEW	NS EW NEW and SEW in parallel
Antenna Currents	NS --4 amperes NEW--6 amperes SEW--6 amperes	NS--15 amperes EW--15 amperes
Non-Driven Antenna Connections at Power Amplifiers	Grounded	Not grounded

76 Hz EM field exposures at control sites, where measurable, generally increased from 1986 to 1987 in proportion to the increase in antenna current. Similarly, at test sites, 76 Hz EM exposures from the nearest antenna element also increased in proportion to the increase in antenna current. Test site EM exposures from the remote antenna element increased at a rate less than proportional to the increase in antenna current in 1987. This was because these exposures are primarily due to cross-coupling between antenna elements, a factor that was reduced in 1987 by the reconfiguration of the EW antenna elements. The EM exposures at most test sites were dominated by the fields of the nearest antenna element versus those of the remote antenna element by a ratio of 10:1 or greater.

3.5.2.4 76 Hz EM Fields (Extrapolated to Full Operating Current)

The 1987 low-power (15 ampere) EM field measurement magnitudes for each antenna element were linearly extrapolated to the planned operating antenna current of 150 amperes, and are presented in tables in the Appendixes. These tables also present extrapolations of the 1986 measurements. Extrapolations were not performed when the low-power measurements were below the sensitivity of the measurement instruments. The 1987 extrapolations are more accurate predictions of the EM field levels at the full operating antenna current, since they are based on measurement data for antenna currents 2.5 to 4 times greater than those used in 1986. The 1987 extrapolations also reflect the final operating antenna configuration of the two east-west antenna elements driven in parallel, as opposed to 1986 when they were driven individually.

The EM field extrapolations are provided as an engineering estimate of the level of field exposures that will be present at study sites when the ELF antennas become fully operational. EM exposure ratios have not been recalculated for the 1987 data, since their primary function was as guidelines for site selection. The EM field extrapolations, however, should be reviewed for each study by the investigators to determine whether the exposure levels between test and control sites, as well as field gradients across the area of a single site, meet individual study requirements for statistical analyses. While site relocations are not feasible, some "fine tuning" of test sites could be undertaken, if necessary, to reduce EM field variability within sites.

3.5.3 In Vitro Studies--EM Exposure

3.5.3.1 Background

The soil amoeba and slime mold studies both employ culture cells that isolate the study organisms from the surrounding soil. This in vitro procedure allows close monitoring of biotic end points without contamination from other soil organisms and bacteria, and is necessary for a controlled study.

Culture cells for both studies are buried in the earth at shallow depths at test and control sites, thus exposing the cultures of soil amoebae and slime mold to the earth's ambient temperature and its variations. It is also desirable to expose the cultures to the same EM environment that they would encounter if living in the soil or litter layer, rather than in or on a culture medium. Ideally, this would be accomplished simply by connecting the culture cell electrodes directly to the earth where they were buried, so that the electric voltages and currents present in the earth could be applied to and flow through the culture medium in the cell. In reality, however, the electric field exposure in the culture cells is complicated by a mismatch between the conductivities of the soil and those of the culture medium. Therefore, external control circuitry must be used to regulate the drive voltages and currents supplied to the culture cells from a set of collector electrodes in the earth.

Two basic culture cell drive control circuits were developed: one for matching electric field exposure and the other for matching current density exposure between the cells and the earth. These drive control circuits and an exposure setup protocol explaining their use are detailed in Appendix L. The magnetic flux is not perturbed by the culture cells, and thus their magnetic flux density is the same as that of the surrounding earth.

3.5.3.2 Slime Mold Exposures

On 24 and 25 April 1985, IITRI field crews set up two matched electric field exposure chambers and one matched current density chamber at each of the three slime mold study sites at the WTF. Drive electrodes were also installed and wired. At that time, the principal investigator was instructed in the protocol for matching the electric field exposure and current density exposure between culture cells and the earth using the exposure chambers. The

investigator set and monitored the culture cells throughout the 1985, 1986, and 1987 seasons.

Exposure chamber voltages V_{CL} and V_R were measured according to the protocol in Appendix L. Culture cell electric fields and current densities were calculated from the exposure chamber measurements as follows:

$$E_{CL} = \frac{V_{CL} (V)}{0.155 \text{ m}} \quad (V/m) \quad (5)$$

Similarly,

$$J_{CL} = \frac{V_R (V)}{R (\Omega) 9 \times 10^{-4} \text{ m}^2} \quad (A/m^2) \quad (6)$$

Here, 0.155 m is the measured distance between electrodes and $9 \times 10^{-4} \text{ m}^2$ is the cross-sectional area of the culture cells' agar growth medium.

Prior to 1987, the exposure chamber voltages V_{CL} and V_R were measured annually by IITRI field crews and weekly by the investigator. In 1987, IITRI designed and installed data loggers that monitored these chamber voltages essentially continuously from 9 July through 19 October. The data loggers were programmed to read chamber voltages once every hour and store the results in memory. The data were retrieved every two weeks by IITRI personnel. IITRI has analyzed these data and has provided the results of its analysis to the study investigator. The data are too extensive to be presented in this report; however, the graph in Figure 10 provides an example of the electric field and current density measured by a data logger at a matched electric field culture cell for a one-week period. The top trace is the electric field and the lower trace is the current density. Values for the fields in this particular example varied by as much as 30% during the one-week period. The large spikes seen on 22 and 23 September correspond to periods when the ELF antenna was off. IITRI has also calculated daily averages of the EM exposures and provided them to the study investigator.

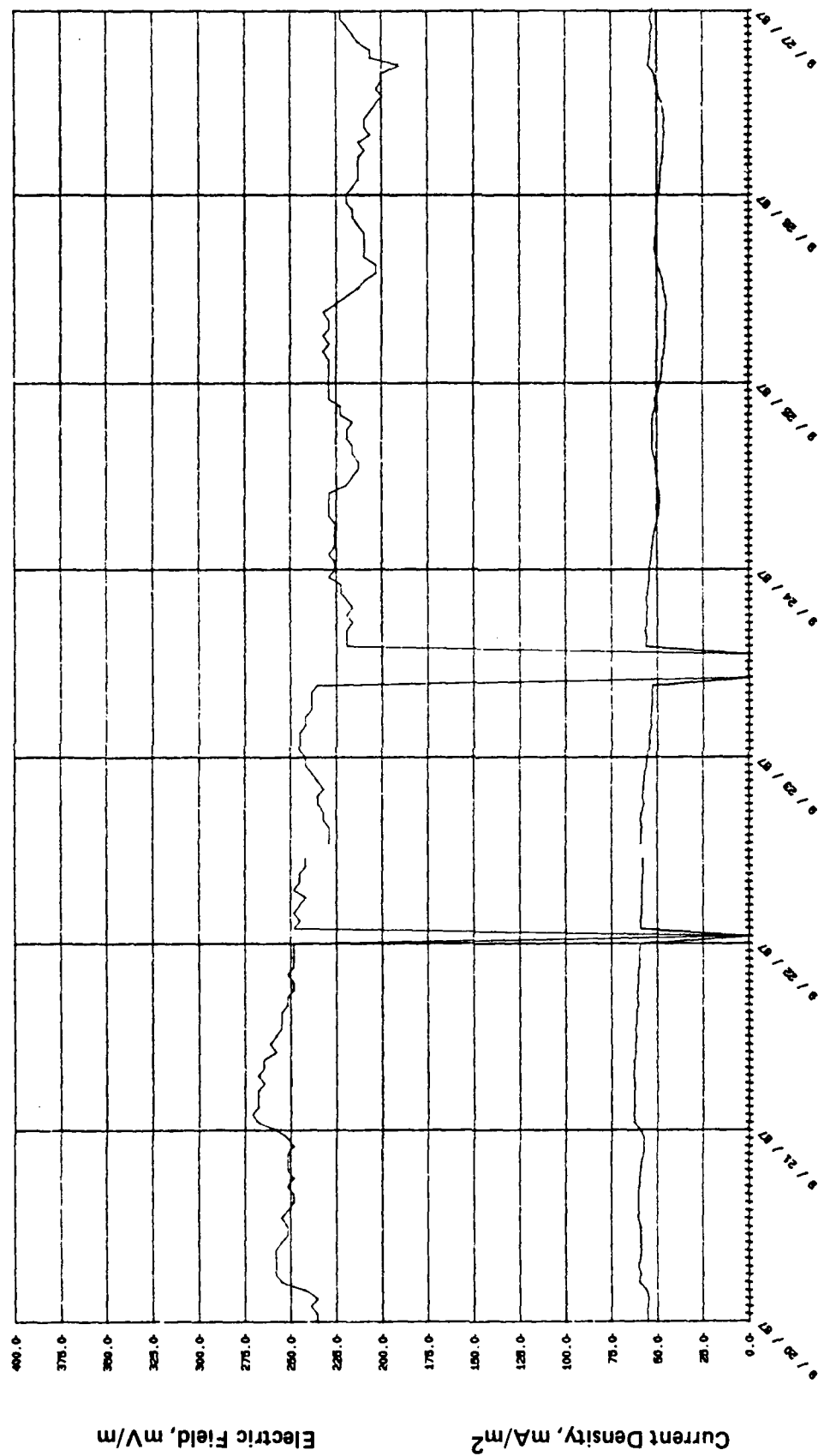


FIGURE 10. SAMPLE PLOT OF ELF EM EXPOSURES RECORDED AT STUDY SITE 7A2 CENTER TEST CHAMBER.

3.5.4 Temporal Variations

In the past, annual field measurements were made in the late summer and early fall. This schedule, however, does not allow one to see the range of possible seasonal variations of the EM fields. Since most study biota remain on the study sites throughout the year, the subject of field variations over the course of a year is addressed below.

It is anticipated that the magnetic field will show little or no seasonal variation, since it is dependent only on the antenna current and wire height and is not affected by surrounding biota.

The transverse electric field in an ROW or a clearing near the antenna is essentially dependent only on the antenna voltage and wire height and is not expected to show significant variation throughout the year. At other locations where the transverse electric field is shielded by foliage or generated as a by-product of the longitudinal electric field, some seasonal variation is expected as plants enter dormancy or as the longitudinal electric field varies.

Longitudinal electric fields are induced by the magnetic field as well as being generated directly by antenna ground terminal currents. In both cases, the fields are dependent on soil conductivity changes resulting from variations in soil moisture and temperature. However, the magnitude of change in electric field for a given change in soil conductivity is not expected to be equal for the two field sources, as discussed below.

The longitudinal electric field along an ELF horizontal ground terminal is generated primarily by current flowing off the ground wire to the earth, and may be approximated as:

$$E \approx \frac{I}{\pi l \sigma} \cdot \frac{x}{x^2 + d^2} \quad (7)$$

where E = longitudinal electric field
 I = antenna current
 l = ground length
 d = depth of buried ground wire
 x = horizontal distance from ground wire
 σ = surface earth conductivity

The longitudinal electric field near an antenna ROW, however, is magnetically induced, and may be approximated as:

$$E = -j f I \mu_0 \ln \left(\frac{1.85}{x \sqrt{2 \pi f \mu_0 \sigma}} \right) - \frac{\pi f I \mu_0}{4} \quad (8)$$

where E = longitudinal electric field
 $j = \sqrt{-1}$
 f = frequency
 I = antenna current
 μ_0 = magnetic permeability in free space
 x = horizontal distance from antenna
 σ = bulk earth conductivity

Equations 7 and 8 illustrate differences in the variation of the longitudinal electric field near ground terminals and antenna ROWs, respectively, as a function of soil conductivity. In both equations, earth conductivity is the only variable expected to show a seasonal variation. However, the two conductivity terms are not equivalent and have different functional relationships within the corresponding electric field equations. The longitudinal electric field near ground terminals is dependent primarily on surface earth conductivity, while bulk earth conductivity determines the electric field near antenna ROWs. The bulk earth conductivity may be considered to be a weighted average of the surface and deep earth conductivities. Because the deep earth conductivity remains stable throughout the year, the bulk earth conductivity will show less seasonal variation than will the surface earth conductivity. In addition, the longitudinal electric field near ground terminals is inversely proportional to conductivity, while the longitudinal electric field along antenna elements is proportional to the natural logarithm of the inverse of the square root of conductivity. Thus, the longitudinal electric field is almost twice as sensitive to changes in conductivity near ground terminals as it is to changes in conductivity along antenna ROWs. This fact, in conjunction with the expected higher variation in surface conductivity, indicates that the greatest seasonal variations in longitudinal electric fields will occur along ground terminal ROWs.

In July 1987, a year-long pilot study was begun of the seasonal variation of longitudinal electric fields and currents at WTF ground terminals. This study, the Grounds Seasonal Variation Pilot Study, measures the longitudinal electric field hourly at seven locations along antenna ground wires. These measurements are made in several media including sandy and loamy soil, gravel, and wetlands. Voltages are measured from copper rod electrodes by a microprocessor-controlled data logger. The data are stored in memory and retrieved monthly. Information obtained from this study will be used to estimate the seasonal variation of the longitudinal electric fields at study sites along ground terminal ROWs in Michigan. These data will also bound the electric field variations at test sites along antenna ROWs, because these variations should be of lesser magnitude.

Although the Grounds Seasonal Variation Pilot Study is not complete, some preliminary analyses already have been performed. These analyses indicate that the longitudinal electric fields in loamy soil tend to increase in the winter months, with overall summer-to-winter variations on the order of 25%. Variations over a one-month period appear to be on the order of 10%. These results are based on a limited sample size over an eight-month period. Figure 11 shows a typical graph of the measured longitudinal electric field at a ground site with loamy soil for the month of October 1987. Note that the vertical lines of the plot indicate periods when the WTF was off for weekly maintenance. A more detailed analysis of the grounds seasonal data and their application to ecological study site electric fields will be conducted in 1988.

Only two study sites in Michigan are actually located in or near ground terminal ROWs. All other test sites are along antenna ROWs and are generally in loamy soil. Seasonal variations in the longitudinal electric field will have the greatest impact on studies investigating subterranean biota, i.e., the soil arthropods and earthworms studies, the upland flora and soil microflora studies, and the soil amoeba studies. The aquatic ecosystems studies have the lowest seasonal variation in the longitudinal electric field due to the consistent moisture content of the Ford River, where these studies are performed. IITRI plans to use data loggers beginning in the spring of 1988 to monitor longitudinal electric fields at the test sites of the soil arthropod

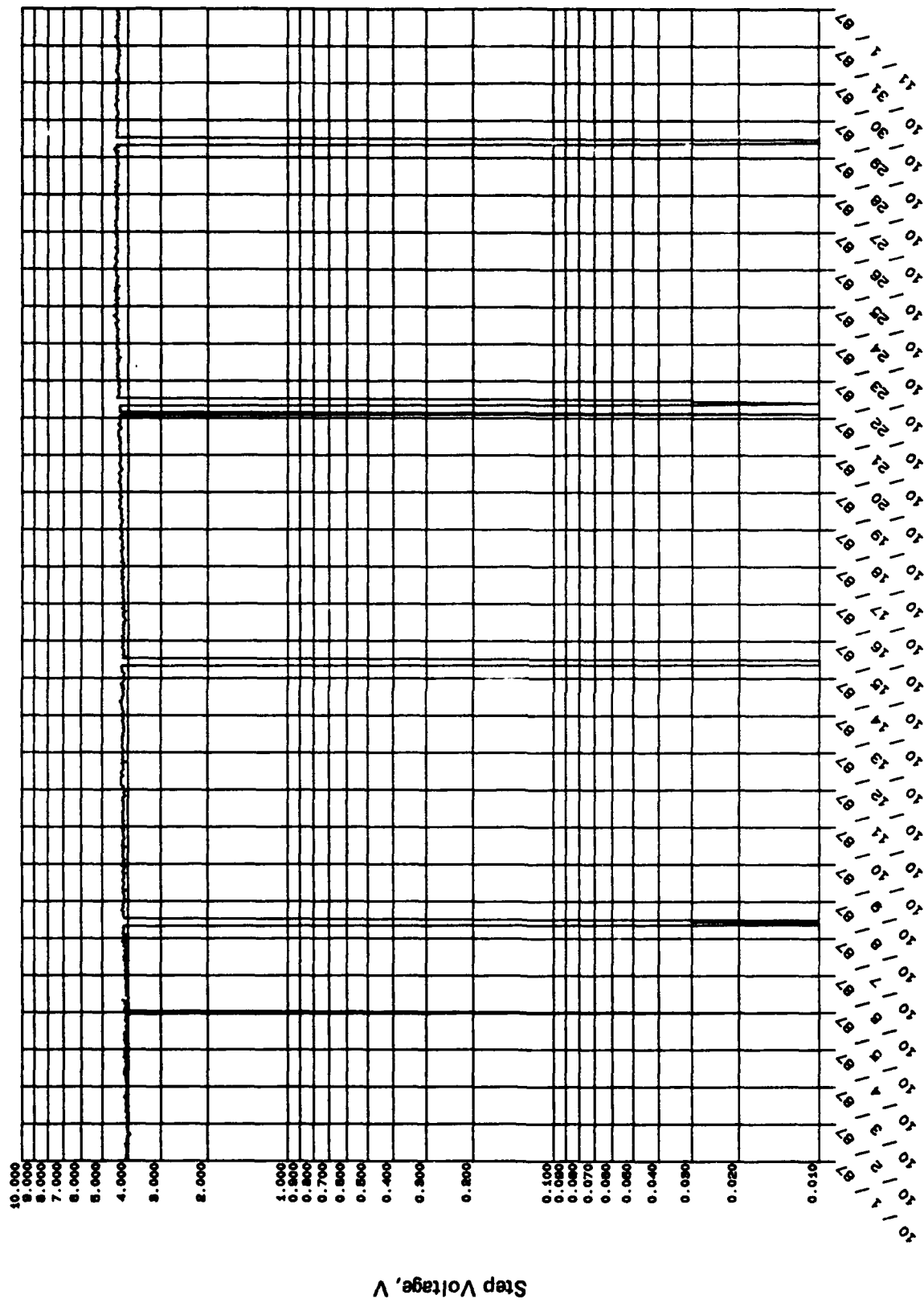


FIGURE 11. PLOT OF LONGITUDINAL ELECTRIC FIELD AT GROUND STUDY SITE WITH LOAMY SOIL -- OCTOBER 1987.

and earthworms studies, the upland flora and soil microflora studies, and the soil amoeba studies.

3.6 Other Support

IITRI personnel performed EM measurements and analyses of the ambient monitoring systems established at the upland flora and soil microflora study sites to ensure electrical safety to the public and study personnel, to mitigate ELF interference with sensor instrumentation, and to protect the monitoring equipment at the study sites against lightning damage. Specific areas of concern were:

- The magnitude of ELF voltages accessible to the public on metallic sensor housings and cables (touch voltage).
- The magnitude of ELF voltages accessible to study personnel on wires and terminals inside sensor housings and junction boxes (craftsman safety).
- The possibility of ELF interference to sensor signals.
- The design of lightning protection for the remote sensors and the Handar 540 monitoring platform.

IITRI personnel made measurements of induced voltages on the monitoring equipment during 15 ampere operation of the MTF. These measurements were linearly extrapolated to an operating antenna current of 150 amperes and found to be within safety standards established by the Navy for ELF voltages induced on metallic equipment and long conductors.* These extrapolations will be checked in the future when the MTF begins operating at higher antenna currents.

IITRI began work on designs for mitigation of ELF interference with sensor instrumentation and on designs for lightning protection for the remote sensors and the Handar 540 monitoring platform. These designs will be completed and implemented in 1988.

*Navy standards limit the sum of 60 Hz and ELF voltages on any conductor that is accessible to the general public to 6 V_{rms}. They also limit the sum of 60 Hz and ELF voltages that are accessible to telephone craftsmen to 50 V_{rms}.

4. ANALYSIS OF TRANSMITTER OPERATIONS

4.1 Operating Log Data Base

In order to calculate the field exposure at a study site, investigators must have both field intensity measurements and data on the operating times of the antennas. Field intensity measurements were discussed in Section 3, and data tables are presented in Appendixes A through I. Data on antenna operating conditions are provided to IITRI by the Navy Project Office. These data include all changes in the operating frequency, modulation, power, and phasing for each antenna element. This log information is entered into a computer-based spreadsheet that allows the generation of operating condition summaries in both graphic and tabular form. Graphic summaries for both the WTF and MTF are presented in this section; more detailed tabular summaries appear in Appendix M. IITRI provides the log data bases to investigators on request via computer disk files.

4.2 Summary of WTF Operations, 1984-1987

The WTF has gone through three stages of development from an operational standpoint. The first stage began in the late 1960s, when the WTF was constructed as a test system for a Navy ELF communications system. The test procedures required various modulations, frequencies, currents, and separate as well as simultaneous powering (at various antenna current phase angles) of the antenna elements. This stage was marked by sporadic periods of operation.

The second stage began in early 1985 with the installation of the new transmitter equipment. This stage was marked by short powerings interspersed with long periods when the antenna was not powered.

After this initial test period was completed, the third stage began: the WTF began operational testing, operating nearly 24 hours a day at a pre-determined current level, frequency, modulation, and antenna phase angle.

The changes from one stage to the next are represented clearly in the WTF monthly operating summary bar graph of Figure 12. This figure shows the hours of operation on a month-by-month basis for the years 1984-1987. Operation of both antenna elements simultaneously was predominant in 1984, with only sporadic operation of the antenna elements individually. There was little operation of the WTF in the first quarter of 1985, followed by intermittent use in

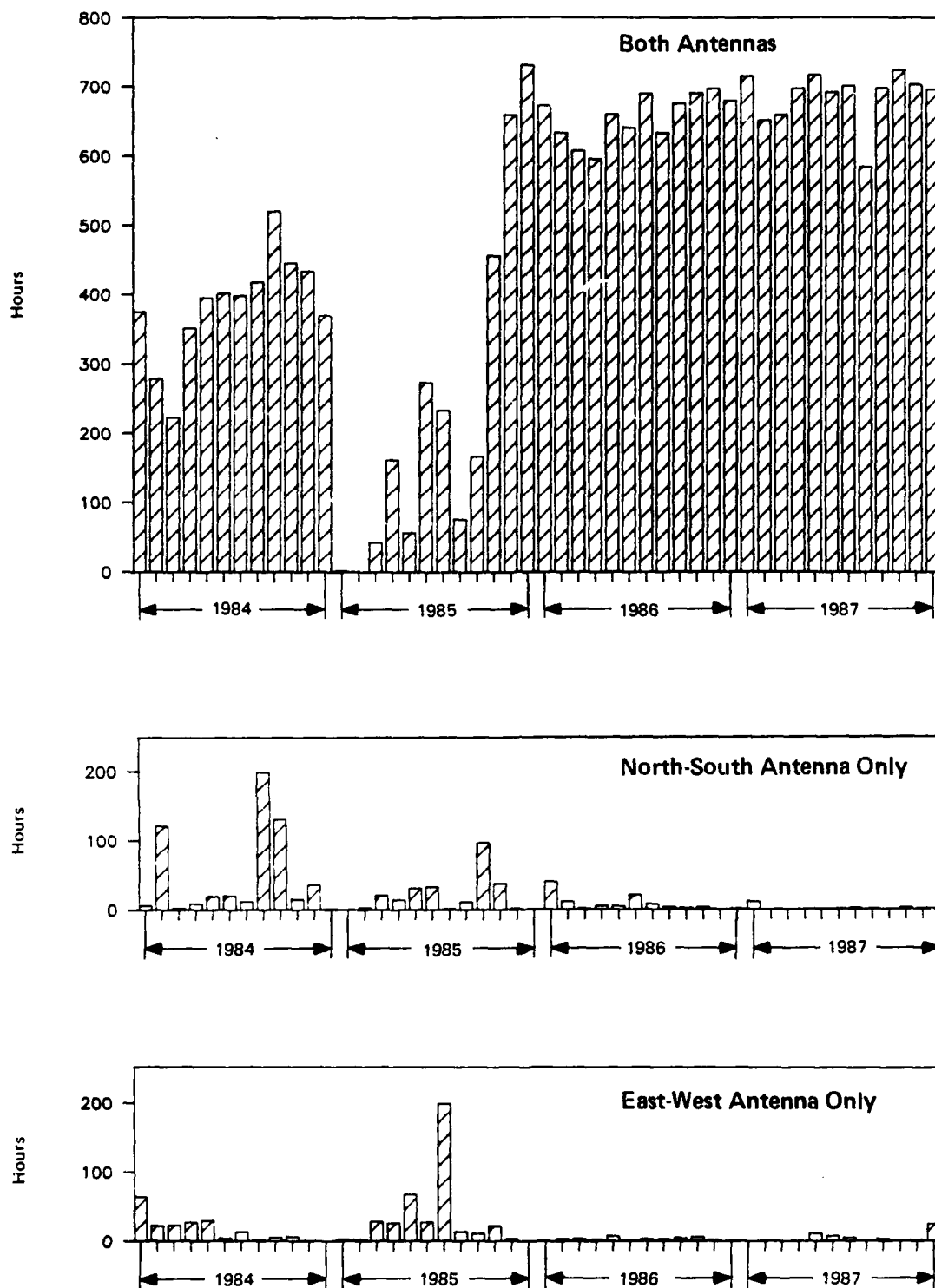


FIGURE 12. WTF MONTHLY OPERATING SUMMARY, 1984-1987.

the second and third quarters, and nearly full-time operation in the fourth quarter. This nearly full-time operation continued through 1986 and 1987.

Figure 13 provides a bar graph of the WTF annual operating summary by mode of operation for 1984-1987. As indicated, the predominant operating condition for all four years was modulated signal transmission at a center frequency of 76 Hz.

The pie charts in Figure 14 provide an annual operating summary by percentage of time per antenna element. As shown, the percentage of time spent in single antenna operation remained relatively constant during 1984 and 1985 and dropped significantly in 1986 and 1987. The total "on" time decreased somewhat in 1985 as a result of the transmitter equipment changeover, and then increased dramatically in 1986 and 1987.

WTF operation from 1984 through 1987 can be summarized as follows:

1984

- The WTF was transmitting about 60% of the time (about 5000 hours) (see Figures 12 and 14).
- About 81% of "on" time was with a modulated 76 Hz signal (see Figure 13).
- About 75% of "on" time was accrued in ~12 hour blocks of continuous operation each day.
- The remaining 25% of "on" time was in short, intermittent time periods, and accounts for most of the transmitter changes in operational mode.
- Less than 2.5% of total "on" time for both antenna elements was at a current level less than 290 amperes.

1985

- The WTF was transmitting about 40% of the time (about 3500 hours) (see Figures 12 and 14).
- About 81% of "on" time was with a modulated 76 Hz signal (see Figure 13).
- About 70% of "on" time was accrued in varying-length blocks of continuous operation each day.
- The remaining 30% of "on" time was in short, intermittent time periods and accounts for most of the transmitter changes in operational mode.
- Less than 1.5% of total "on" time for both antenna elements was at a current level less than 290 amperes.

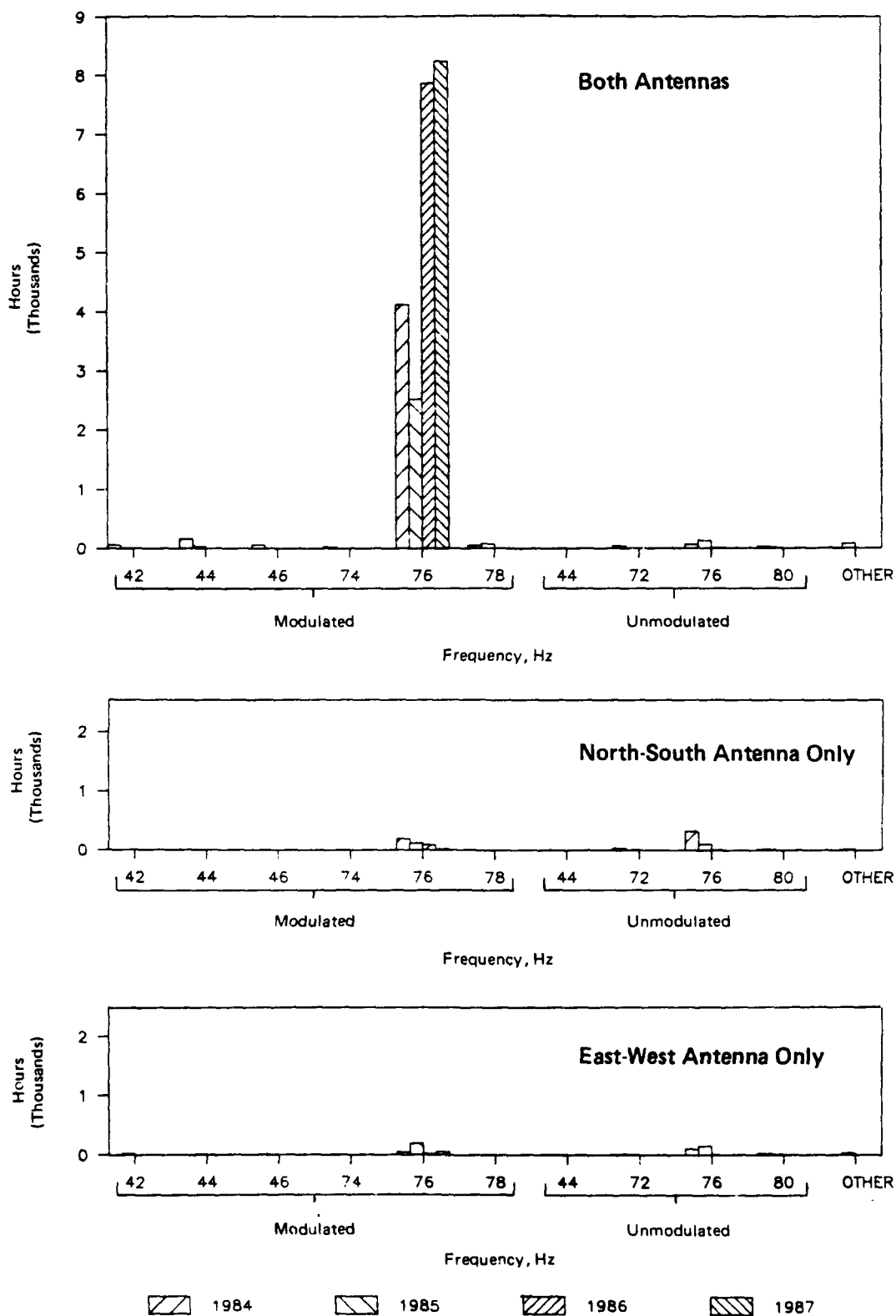


FIGURE 13. WTF OPERATING MODE SUMMARY, 1984-1987.

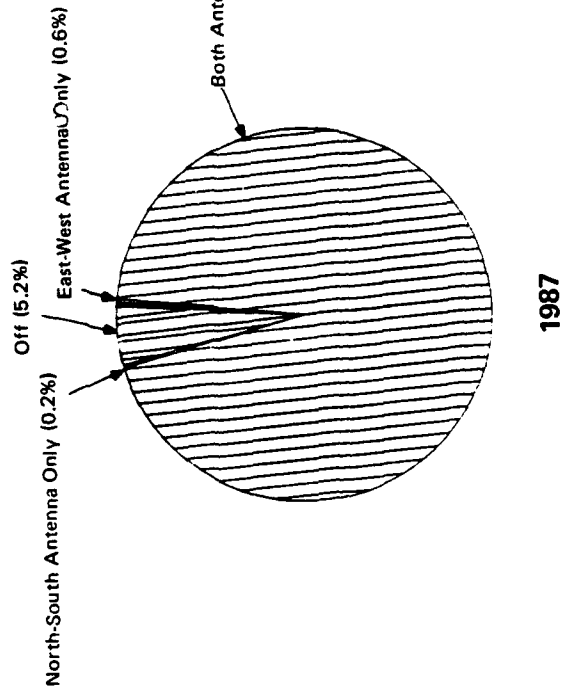
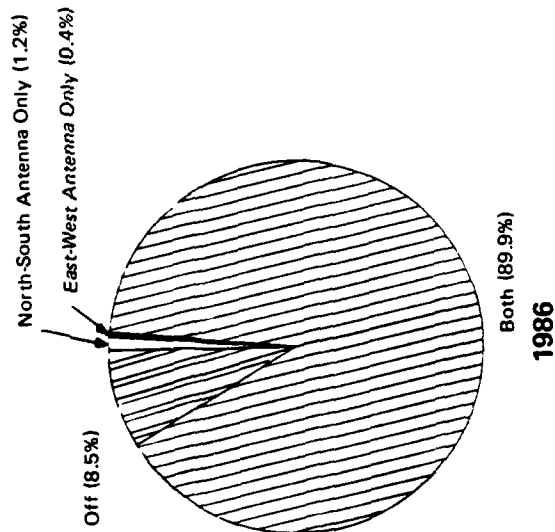
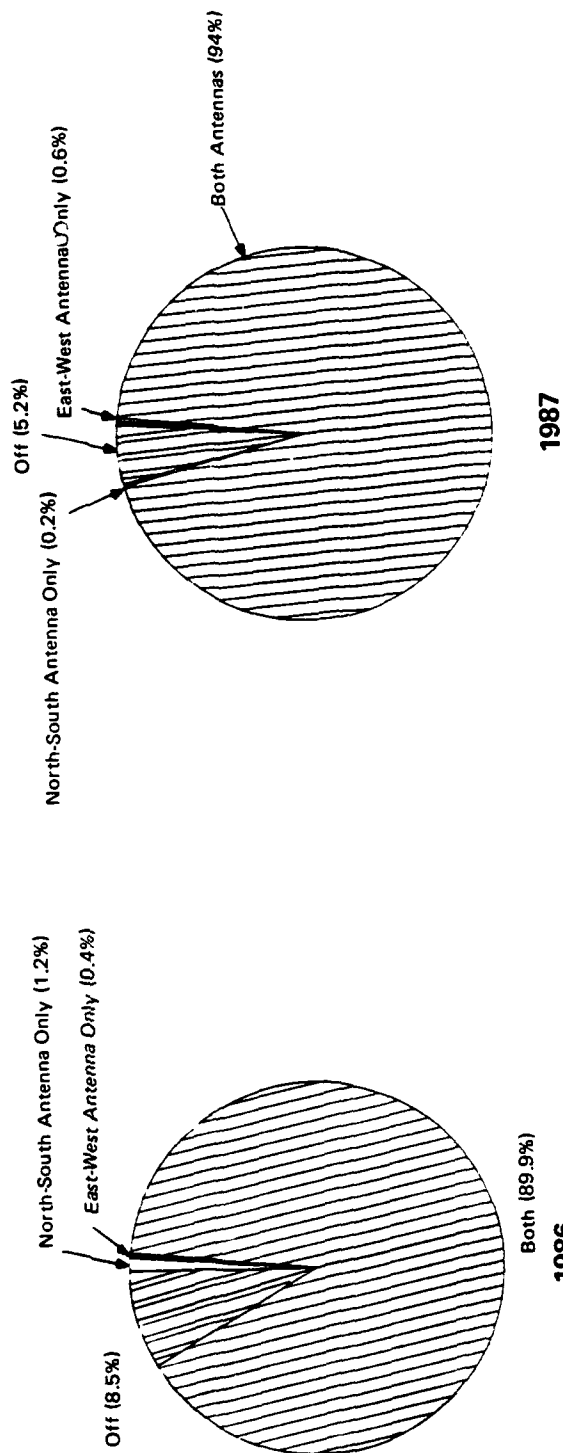
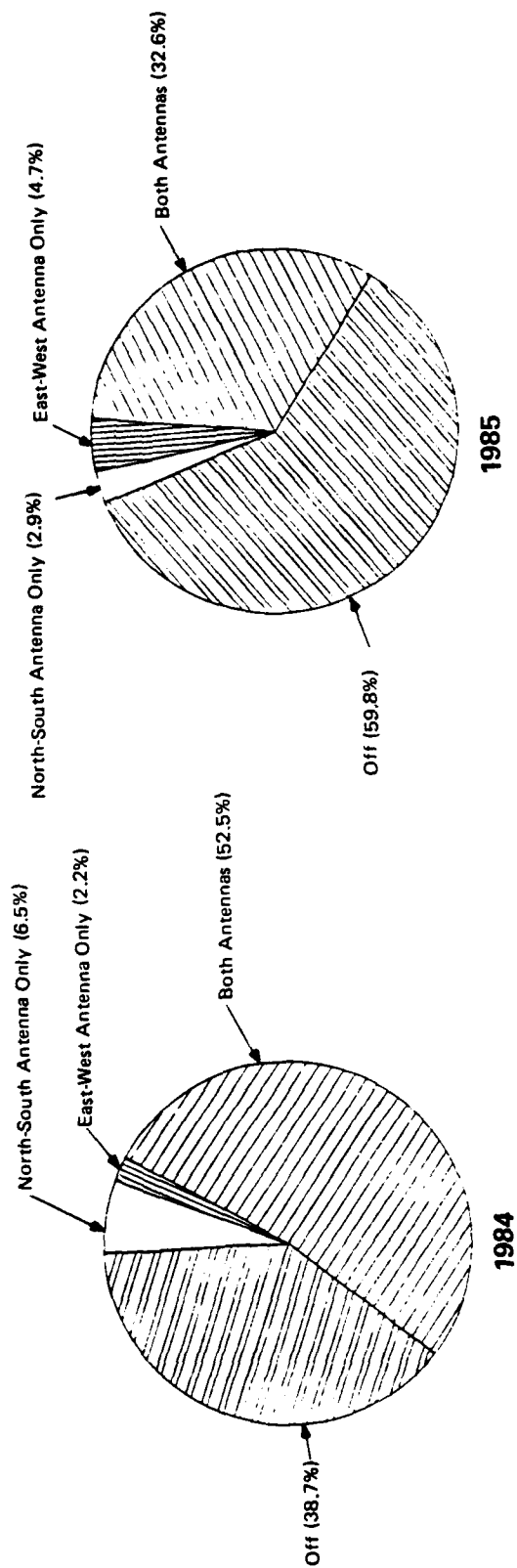


FIGURE 14. WTF OPERATING SUMMARY: PERCENTAGE OF TIME PER ANTENNA ELEMENT, 1984-1987.

1986

- The WTF was transmitting about 91% of the time (about 8000 hours) (see Figures 12 and 14).
- About 99.8% of "on" time was with a modulated 76 Hz signal (see Figure 13).
- The transmitter was off weekly for a four-hour scheduled maintenance period.
- The transmitter was off intermittently because of equipment failure or unscheduled maintenance.
- Less than 1% of total "on" time for both antenna elements was at a current level less than 290 amperes.

1987

- The WTF was transmitting about 95% of the time (about 8300 hours) (see Figures 12 and 14).
- More than 99.9% of "on" time was with a modulated 76 Hz signal (see Figure 13).
- The transmitter was off weekly for a four-hour scheduled maintenance period.
- The transmitter was off intermittently because of equipment failure or unscheduled maintenance (note maintenance period from 24 to 28 August).
- Less than 1% of total "on" time for both antenna elements was at a current level less than 300 amperes.

4.3 Summary of MTF Operations, 1986-1987

The MTF will go through several stages of development, as did the WTF. The antenna elements at the MTF were first operated in March 1986. The signal was a low current unmodulated (continuous wave) signal. The three antenna elements (NS, NEW, and SEW) were operated individually and intermittently through 1986, predominantly at 4, 6, or 10 amperes. In 1987 almost all testing was performed under an unmodulated, 15 ampere test condition. Differences in operation between 1986 and 1987 consisted of the two east-west antenna elements (NEW, SEW) being operated in parallel in 1987 rather than independently as in 1986. These two elements will remain in parallel in the future as well. Testing still remains to be performed with a 75 ampere antenna current in 1988 before the MTF becomes fully operational with a 150 ampere antenna current.

Figure 15 shows the hours of operation for each antenna element on a month-by-month basis for 1986 and 1987. As can be seen from this figure, operation began in March 1986 and continued through October, then resumed in

April 1987 and continued through November. The operating currents are not shown in the figure. In 1986, the NS antenna element carried a current of 4 amperes for more than 99% of its operating time, the NEW antenna element carried a current of 6 amperes for more than 99% of its operating time, and the SEW antenna element carried both 6 and 10 ampere currents for approximately equal time periods during its operation. In 1987, minimal testing was performed in April and May using 3, 4, and 6 ampere currents. Extensive testing was performed from June through November with 15 ampere currents in each element. During this 15 ampere testing period in 1987, virtually all transmitter operations were conducted according to a 15-minute rotational schedule, referenced to quarter hours as follows:

- 5 minutes--both elements off
- 5 minutes--NS element only on
- 5 minutes--EW element pair only on

MTF operational logs supplied to IITRI list specific times at which such cycles begin and end. The actual operating times were estimated by assuming a 33% duty cycle for each element during the testing period.

The pie charts in Figure 16 provide an annual operating summary by percentage of time per antenna element for 1986 and 1987. In 1986, the total "on" time for all antenna elements was 1.8% of the year; this time was split rather evenly among the NS, NEW, and SEW antenna elements. In 1987, the total "on" time for all antenna elements was 4.5%; this time was split evenly between the NS and EW elements.

MTF operation in 1986 and 1987 can be summarized as follows:

1986

- The MTF was transmitting about 1.8% of the time (about 160 hours) (see Figures 15 and 16).
- About 98% of "on" time was with a continuous wave 76 Hz signal.
- Antenna elements were operated individually.
- Primary operating currents were 4 and 6 amperes for the NS and NEW antenna elements, respectively, and both 6 and 10 amperes for the SEW antenna element.

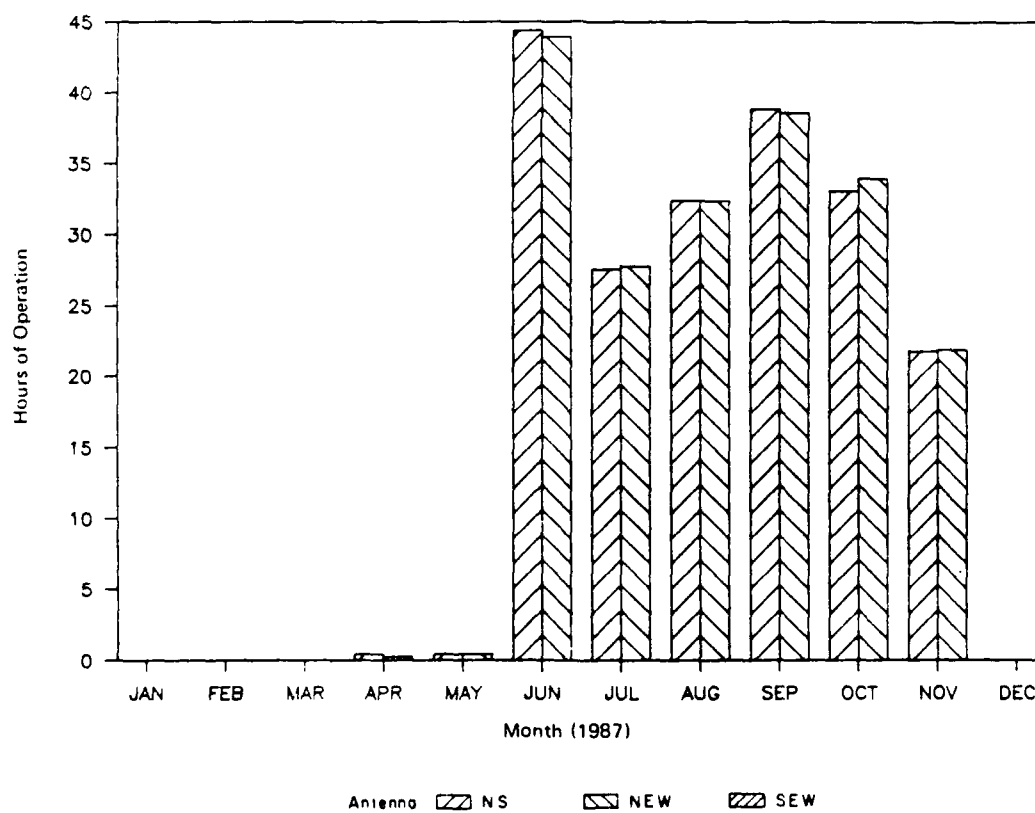
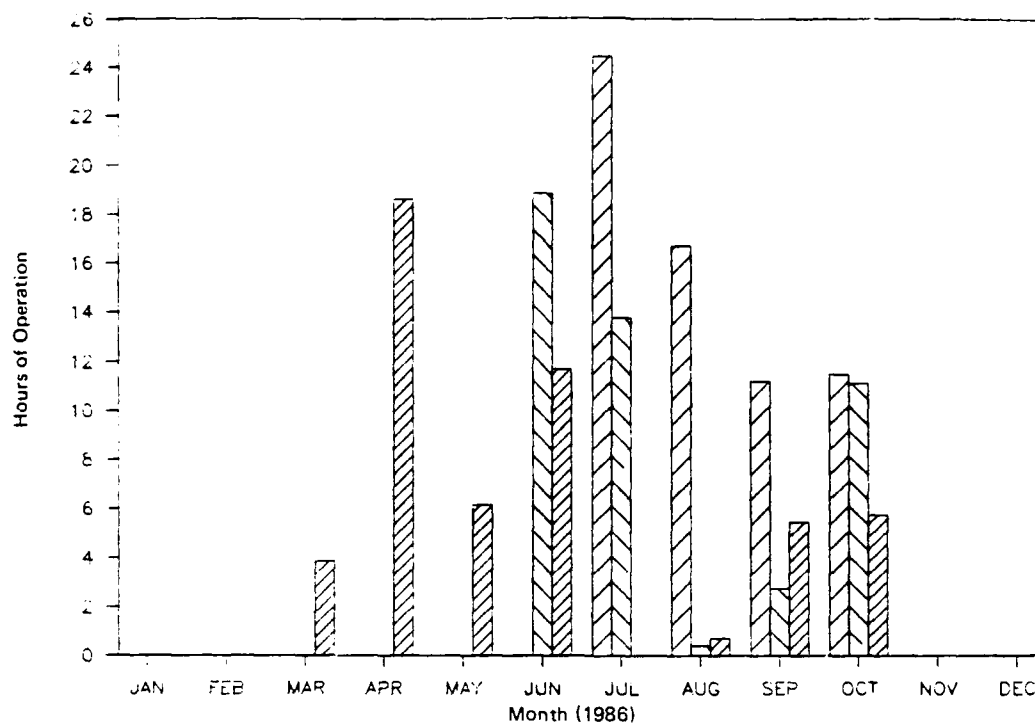


FIGURE 15. MTF MONTHLY OPERATING SUMMARY, 1986-1987.

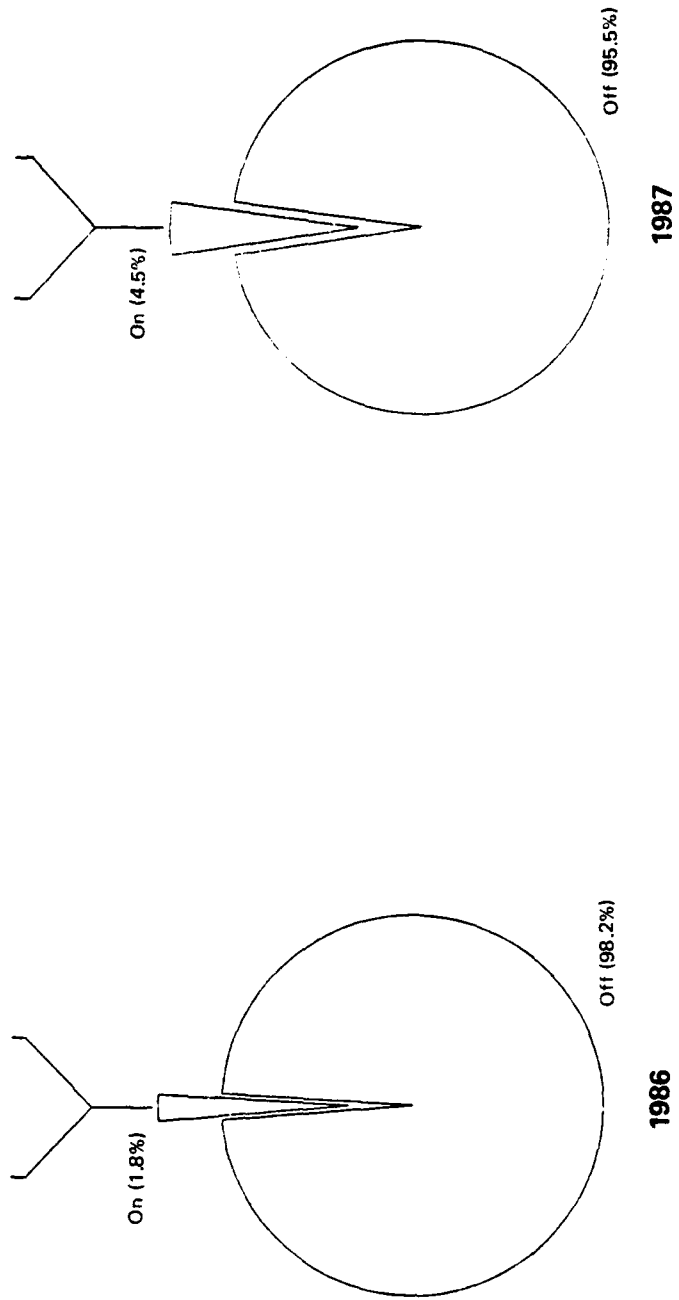
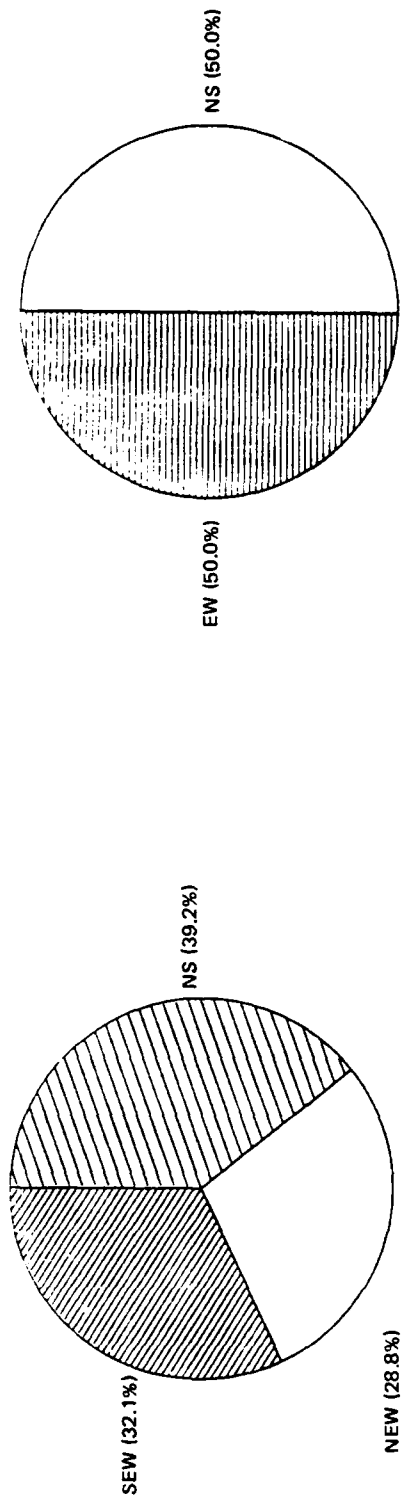


FIGURE 16. MTF OPERATING SUMMARY: PERCENTAGE OF TIME PER ANTENNA ELEMENT, 1986-1987.

1987

- The MTF was transmitting about 4.6% of the time (about 400 hours) (see Figures 15 and 16).
- 100% of "on" time was with a continuous wave 76 Hz signal.
- The NS element and EW element pair were operated individually.
- 99.6% of the operating time in 1987 was with a 15 ampere current.

5. CONCLUSIONS AND DISCUSSION

Annual EM field measurement surveys were performed at both Wisconsin and Michigan study sites during August, September, and October of 1987. Measurements were made at a total of 266 points at 74 study sites, compared with 244 measurement points at 69 sites in 1986. The five new sites in 1987 consisted of two proposed sites for the relocation of the animal holding facilities for the small mammals and nesting birds studies and three sample collection points for the upland flora and soil microflora studies. Most changes in measurement points involved the addition of new transects at the small mammals and nesting birds study sites.

The measurement protocol used in Wisconsin in 1987 was the same as that used in 1985 and 1986. All points measured in 1986 were remeasured in 1987 with the exception of 10C10-2 on the Brunet River transect, which was relocated to 10C10-3 due to logging activities. Yearly measurement variations were within expected limits at all sites in Wisconsin. Significant changes occurred only in the longitudinal electric fields at site 8A2, most likely as a result of changes in soil conductivity.

The MTF was operational for a second season in 1987, under conditions different from those that prevailed in 1986. These differences included a higher operating current, operation of the two EW antenna elements in parallel, and changes in the antenna-to-power amplifier configuration of the non-active antenna element during daily operation in 1987. These differences impacted both the 76 Hz and 60 Hz EM fields.

In Michigan, new measurement transects were established at the Cleveland Homestead, North Turner Road, and Ford River North and South sites for the small mammals and nesting birds studies. Single measurement points were added at the Panola Plains site, the two proposed relocation sites for the animal holding facilities for the small mammals and nesting birds studies, the Ford River North site for the native bees studies, and three new sample collection sites for the upland flora and soil microflora studies.

The 60 Hz fields at the laboratory holding facility (site 1L1), the red maple leaf collection point (site 4S1), and the oak leaf collection point (site 4S3) were all greater than site selection criteria dictate. The study investigator suggested a new site for the animal holding facilities, and new

sites are being considered for the leaf collection points. EM field measurements were made at these proposed sites, which were determined to be compatible with all site selection criteria.

IITRI designed data loggers and installed them at the three slime mold study sites in Wisconsin. These data loggers recorded electrical chamber data on an hourly basis, from 9 July to 19 October, and stored it in memory. The data were retrieved once every two weeks and used to calculate the electric field and current density within each culture cell.

Seasonal variations of the longitudinal electric field are currently under investigation. Data loggers similar to those used for the slime mold study chambers have been installed at seven locations along the WTF ground terminals for the Grounds Seasonal Variation Pilot Study. These data loggers measure the longitudinal electric field on an hourly basis in sandy and loamy soils, gravel, and wetlands. A complete year of data will be available in the summer of 1988, at which time the data will be analyzed to more accurately determine the variation of the longitudinal electric field near ground terminals as a function of day-to-day and seasonal environmental changes. The seasonal variation of the longitudinal electric fields at ground terminals will be used to estimate the seasonal variations of these fields at the Ecological Monitoring Program study sites.

IITRI also performed EM measurements and analyses of the ambient monitoring systems for the upland flora and soil microflora studies to determine coupled ELF safety and interference voltages and to develop lightning protection schemes for the systems. Primary questions of safety with regard to coupled ELF voltages have been answered. The design of ELF interference mitigation and lightning protection techniques was begun and will be implemented in 1988.

The slime mold and wetlands studies had their final field season in Wisconsin in 1987. The bird species and communities studies, which began later, will continue in Wisconsin beyond 1987. No significant changes in the mode of operation of the WTF are expected in 1988. Therefore, the 1988 annual field measurements for the bird species and communities studies in Wisconsin are expected to be made under the same protocol as in 1985-1987.

The MTF is expected to operate in 1988 with the same antenna configuration as in 1987. However, a 75 ampere antenna current is likely during annual field measurements, and 150 ampere testing may begin in the second quarter of 1989. Measurement protocols to be used in 1988 will be determined by the actual antenna status at that time.

APPENDIX A
SMALL MAMMALS AND NESTING BIRDS STUDIES

SMALL MAMMALS AND NESTING BIRDS STUDIES

On 24 and 28-30 September and on 1, 5, 6, and 8 October 1987, IITRI field crews made ELF electromagnetic (EM) field measurements at 61 measurement points at a total of five test sites, four control sites, three (bird) displacement sites, and the laboratory site for the small mammals and nesting birds studies. The nine test and control sites were all measured in the three previous years; the laboratory site and displacement sites were added to the measurement regime in 1986. On 11 December 1987 EM field measurements were made at two possible alternate sites for the holding facilities used prior to animal laboratory testing.

Several new measurement points were added in 1987, in the pattern of a transect perpendicular to the antenna, to better define the spatial variation of the 76 Hz EM fields. A total of five new transects were established: one each at Cleveland Homestead, North Turner Road, and Ford River South, and two at Ford River North (site numbers 1T2, 1T4, 1T6, and 1T5, respectively). A single measurement point was added at Panola Plains (site number 1C4). A single measurement point was also added at each of the two possible new holding facility sites (1L2 and 1L3). In summary, 23 new measurement points were added and six were dropped in 1987. The positions of all sites relative to the MTF are shown on the composite map in Figure A-1. The site numbers listed on the map are those used by IITRI. Table A-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. Details of measurement locations within sites are shown in Figures A-2 through A-15.

The small mammals and nesting birds studies monitor parental care, nestling growth and maturation, fecundity, homing, activity patterns, embryological development, and metabolic physiology. The electric and magnetic fields in the air are considered important factors to be examined in orientation and other behavior patterns of birds. The electric and magnetic fields in the earth near the surface are important to the small mammals studies.

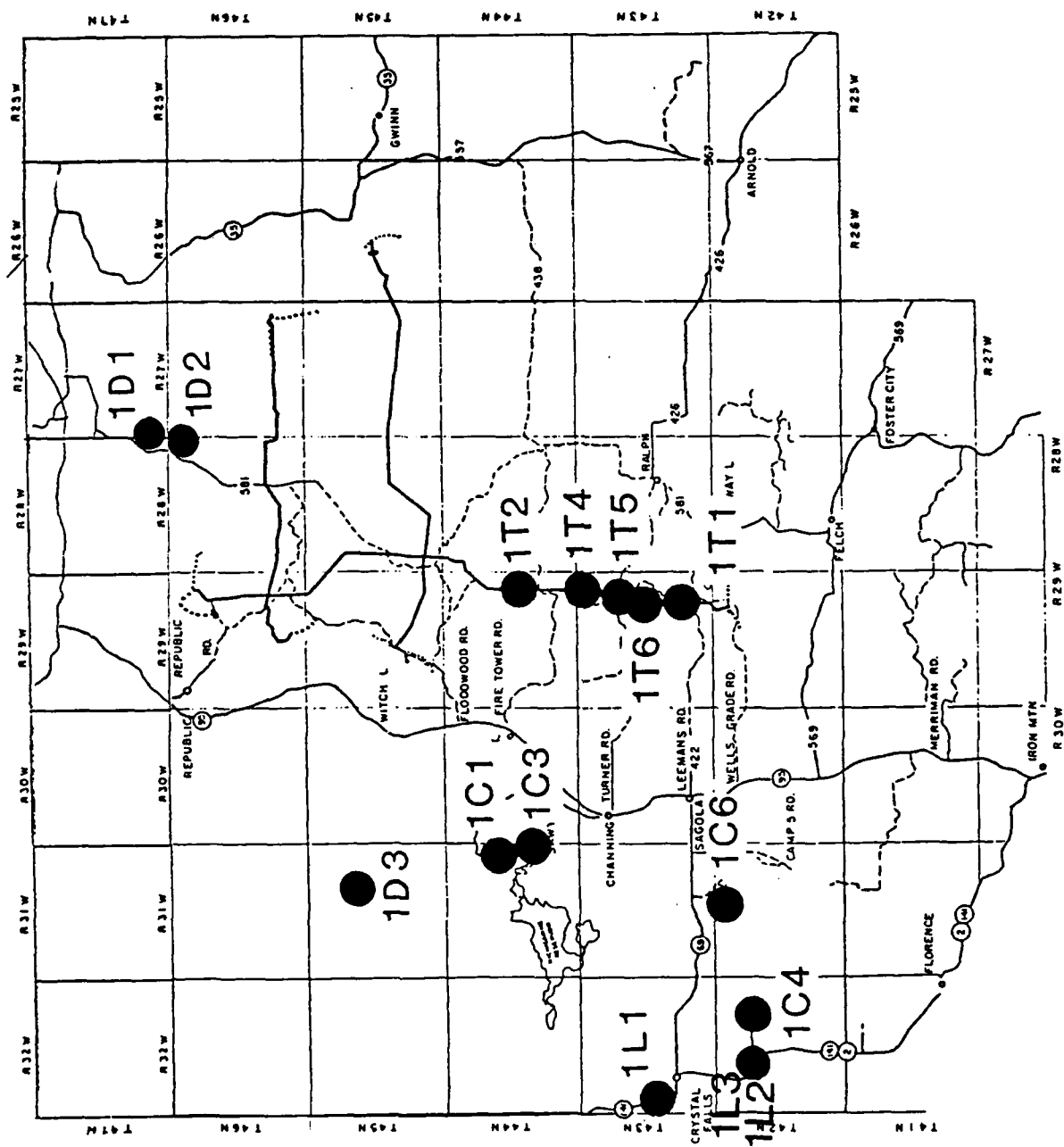


FIGURE A-1. POSITIONS OF SMALL MAMMALS AND NESTING BIRDS STUDY SITES RELATIVE TO MICHIGAN TRANSMITTING FACILITY ANTENNA ELEMENTS.

TABLE A-1. SITE NO. CROSS-REFERENCE
Small Mammals and Nesting Birds Studies

IITRI Site No.	Investigator's Site Name	Location		
		Township	: Range	: Section(s)
1T1	Pirilot Road	T43N	: R29W	: 23, 26
1T2	Cleveland Homestead	T44N	: R29W	: 25
1T4	North Turner Road	T43N	: R29W	: 1
1T5	Ford River North	T43N	: R29W	: 14
1T6	Ford River South	T43N	: R29W	: 14
1C1	Michigamme North	T44N	: R31W	: 13
1C3	Michigamme South	T44N	: R31W	: 24
1C4	Panola Plains	T42N	: R32W	: 10
1C6	Tachycineta Meadow	T42N	: R31W	: 3
1D1	Cleveland Homestead Displacement	T47N	: R28W	: 36
1D2	North Turner Displacement	T46N	: R28W	: 12
1D3	Panola Plains Displacement	T45N	: R31W	: 14
1L1	Crystal Falls Lab	T43N	: R32W	: 29
1L2	Candidate Holding Facility 1	T42N	: R32W	: 9, 16
1L3	Candidate Holding Facility 2	T42N	: R32W	: 8, 9

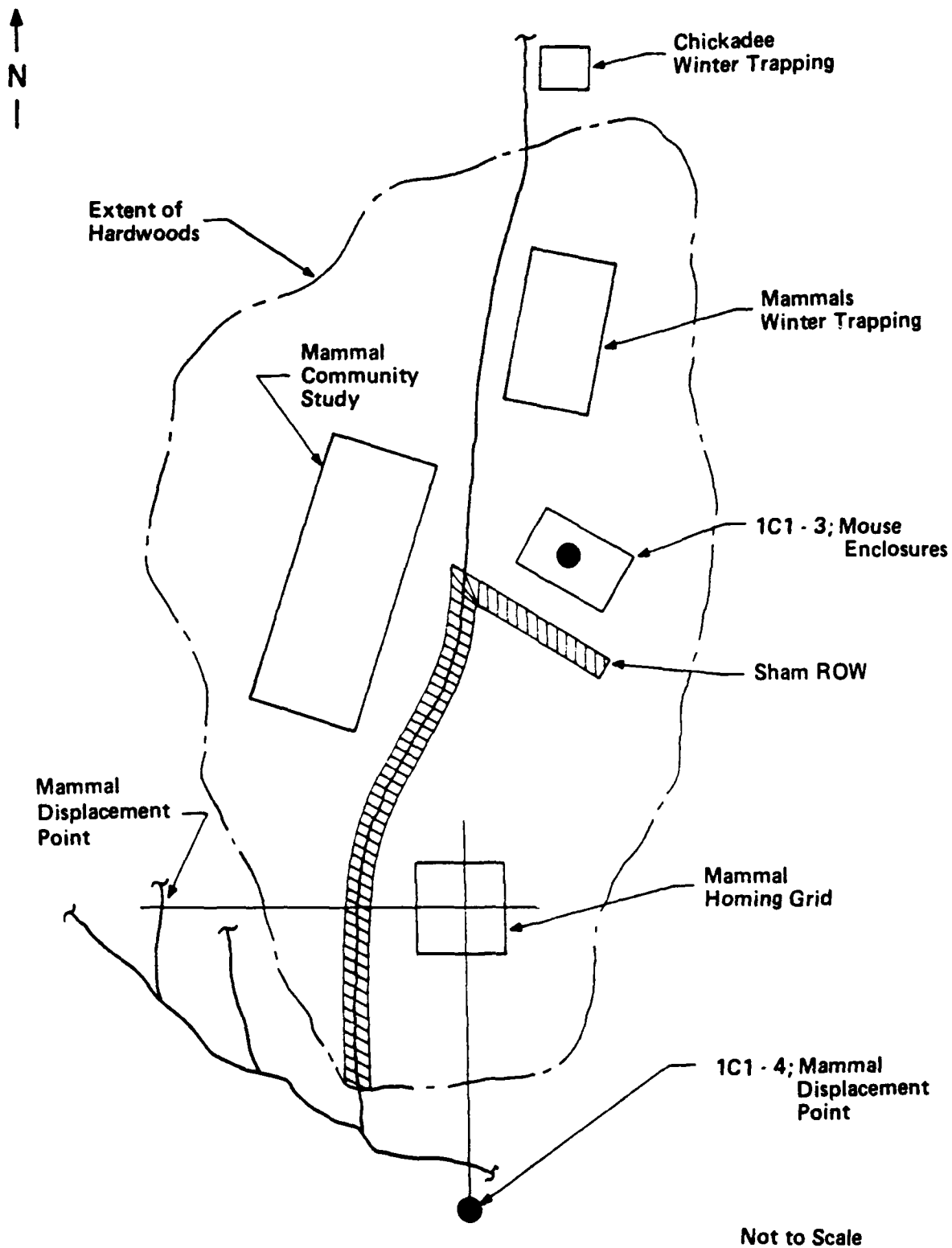


FIGURE A-2. MEASUREMENT POINTS AT MICHIGAMME NORTH; 1C1 - 3, 4.

↑
N

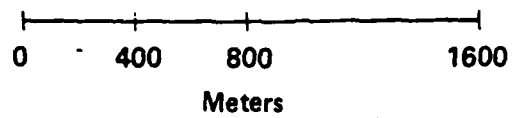
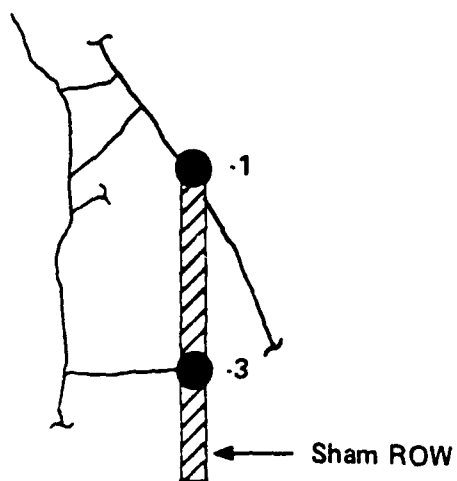


FIGURE A-3. MEASUREMENT POINTS AT MICHIGAMME SOUTH; 1C3 - 1, 3.

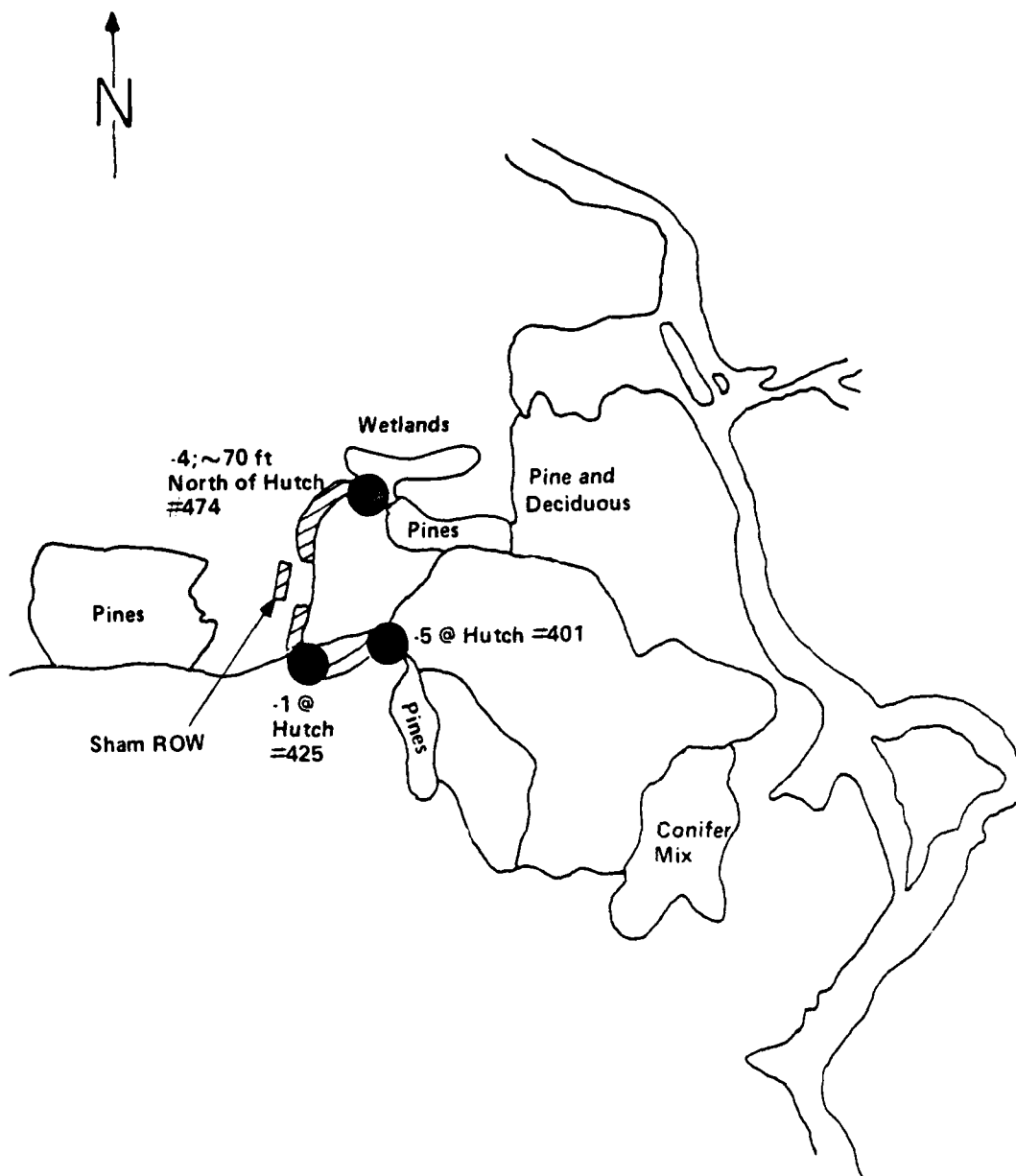


FIGURE A-4. MEASUREMENT POINTS AT PANOLA PLAINS; 1C4-1, 4, 5.

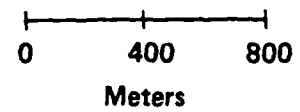
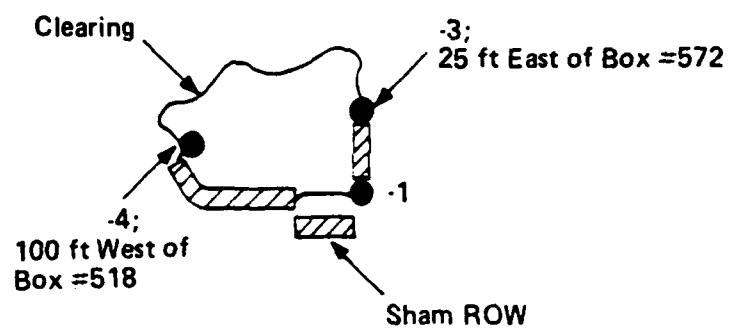


FIGURE A-5. MEASUREMENT POINTS AT TACHYCNETA MEADOW; 1C6 - 1, 3, 4.

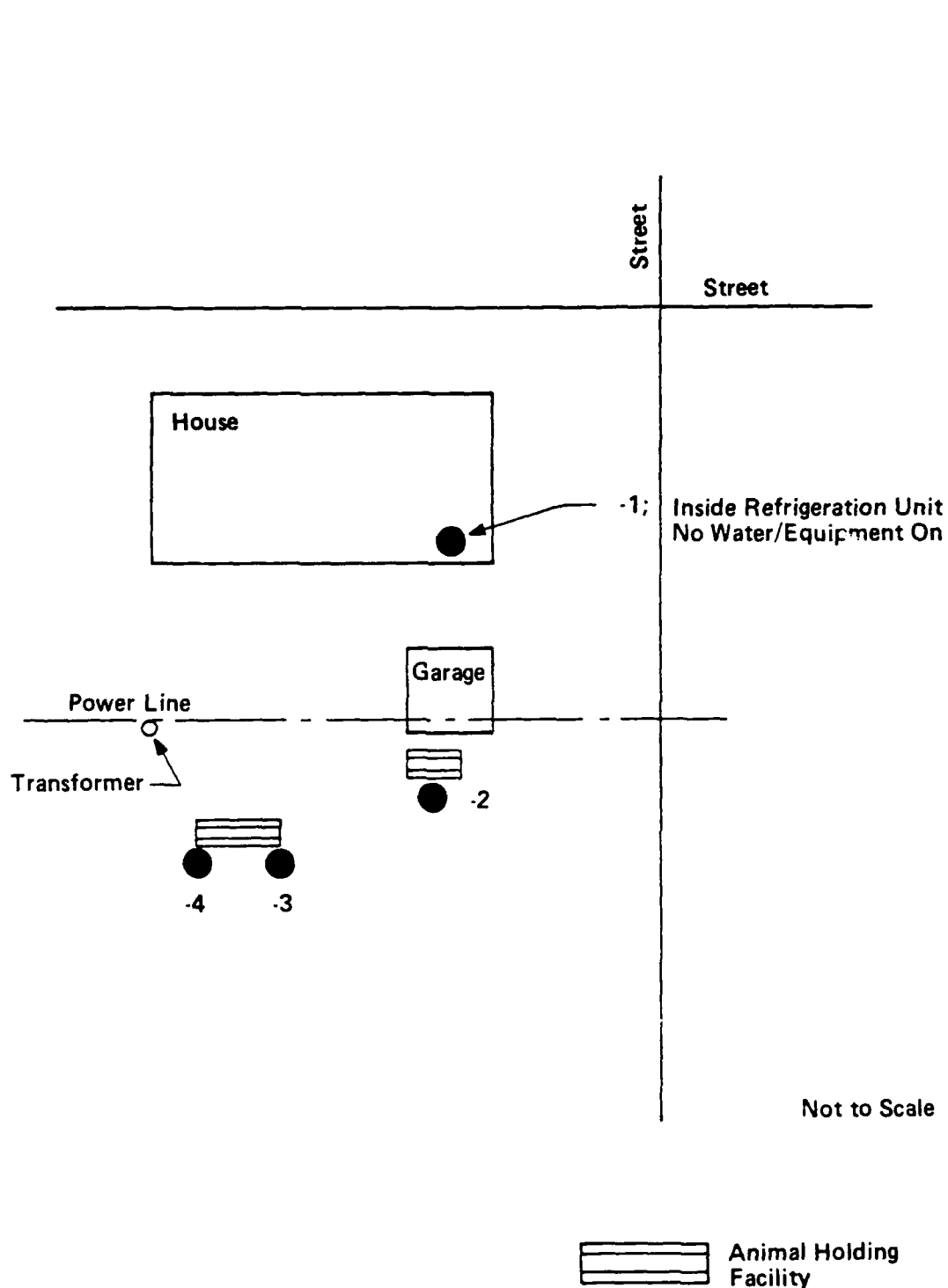


FIGURE A-6. MEASUREMENT POINTS AT MAMMAL LABORATORY; T-1 - 1 THROUGH 4.

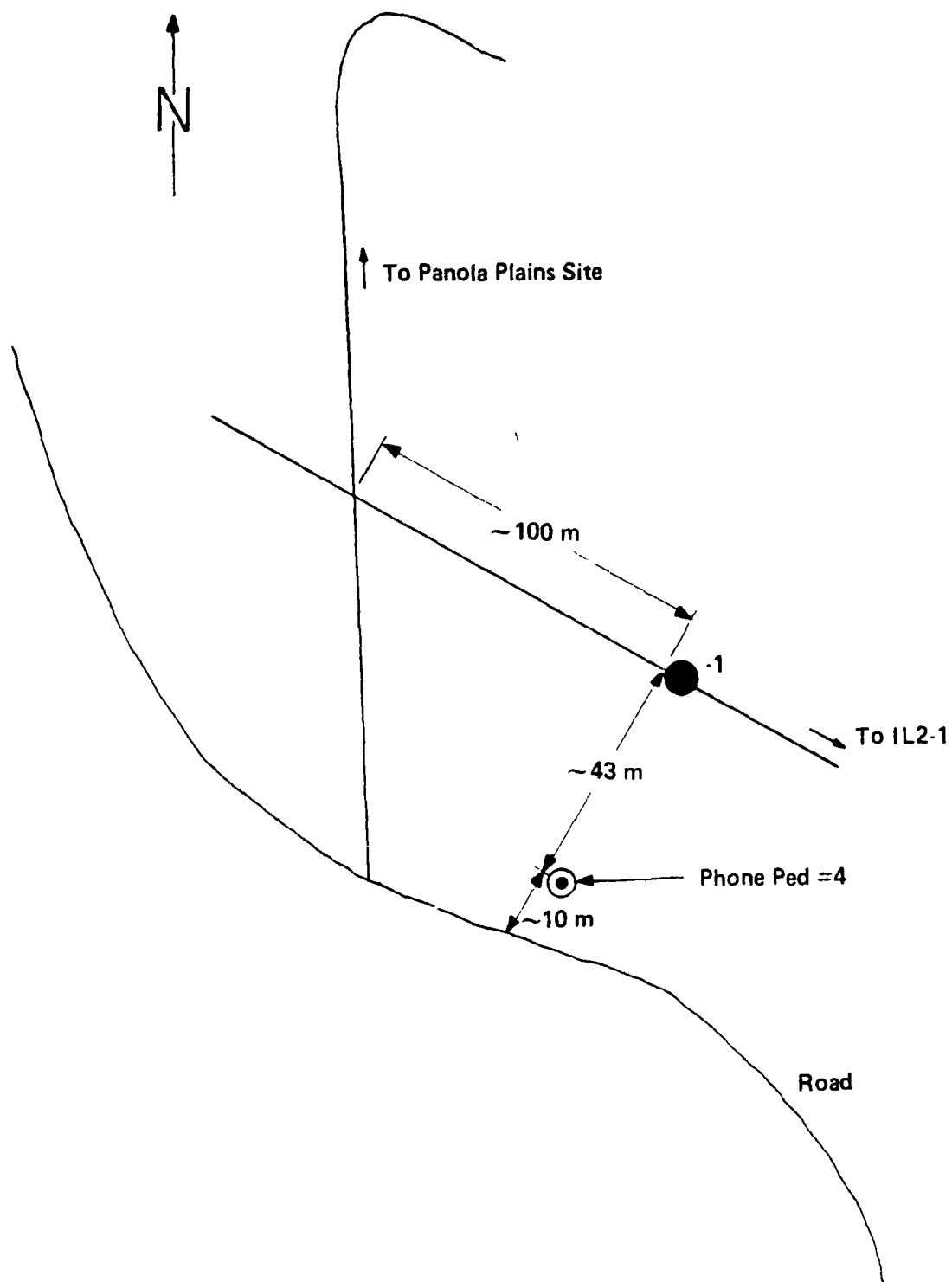
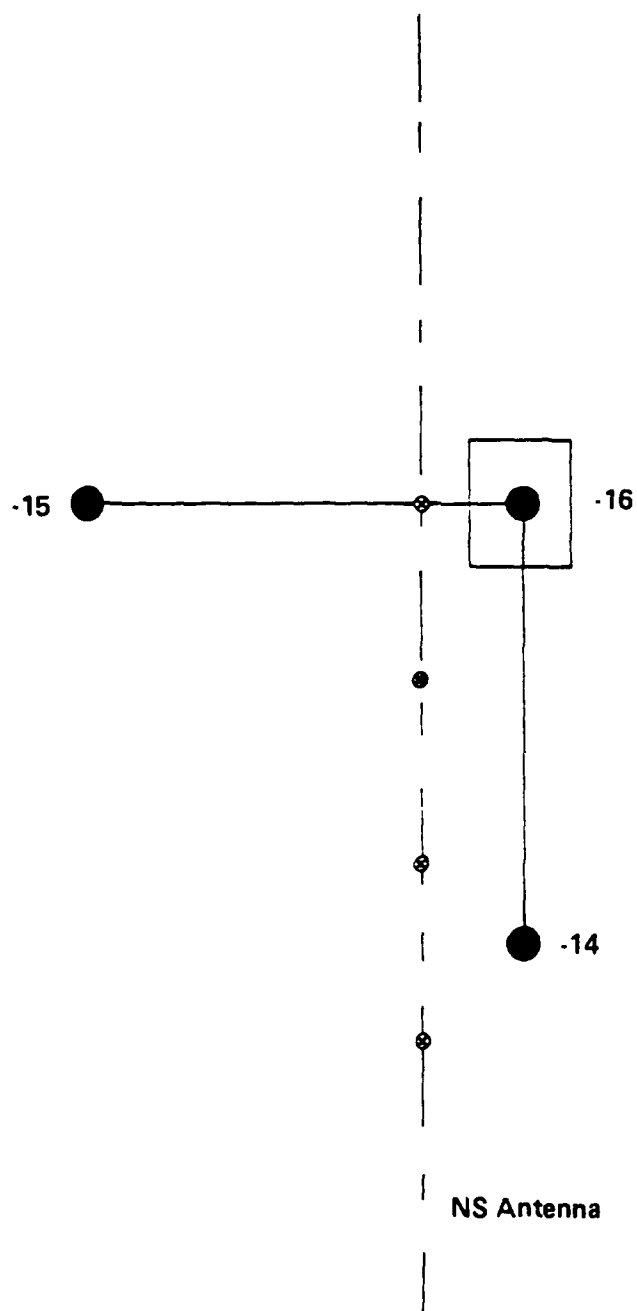
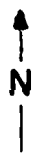


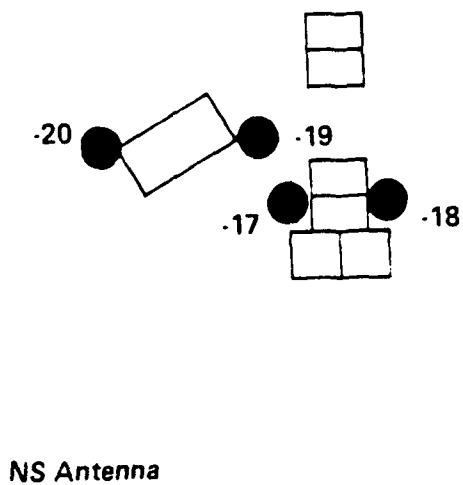
FIGURE A-8. MEASUREMENT POINT AT CANDIDATE HOLDING FACILITY II; 1L3-1.



Not to Scale

FIGURE A-9. MEASUREMENT POINTS AT PIRLOT ROAD MAMMAL DISPLACEMENT;
1T1 - 14, 15, 16.

↑
N



Not to Scale

FIGURE A-10. MEASUREMENT POINTS AT PIRLOT ROAD MOUSE ENCLOSURES;
1T1 - 17 THROUGH 20.

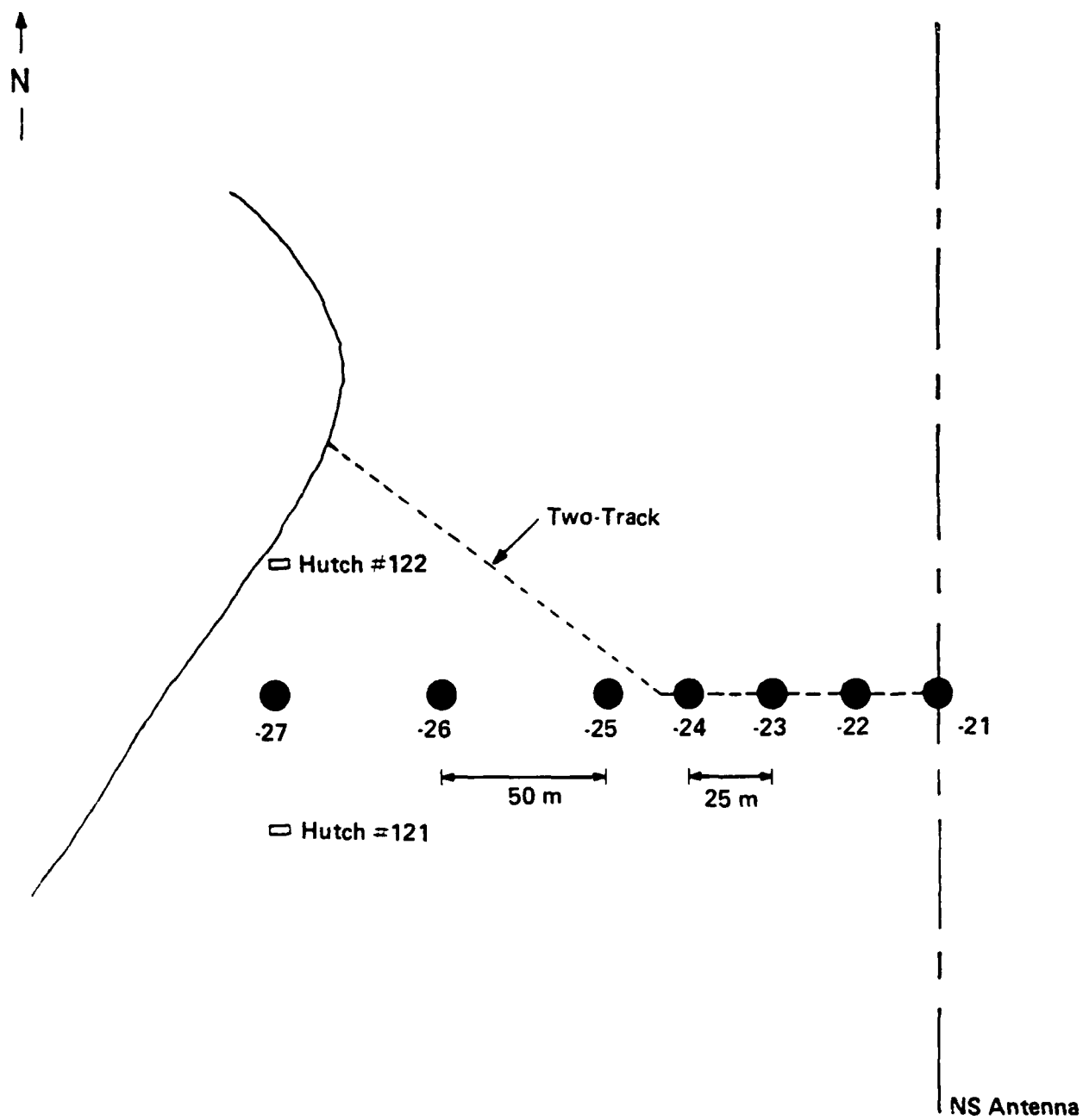


FIGURE A-11. MEASUREMENT POINTS AT PIRLOT ROAD NEST BOXES;
1T1 - 21 THROUGH 27.

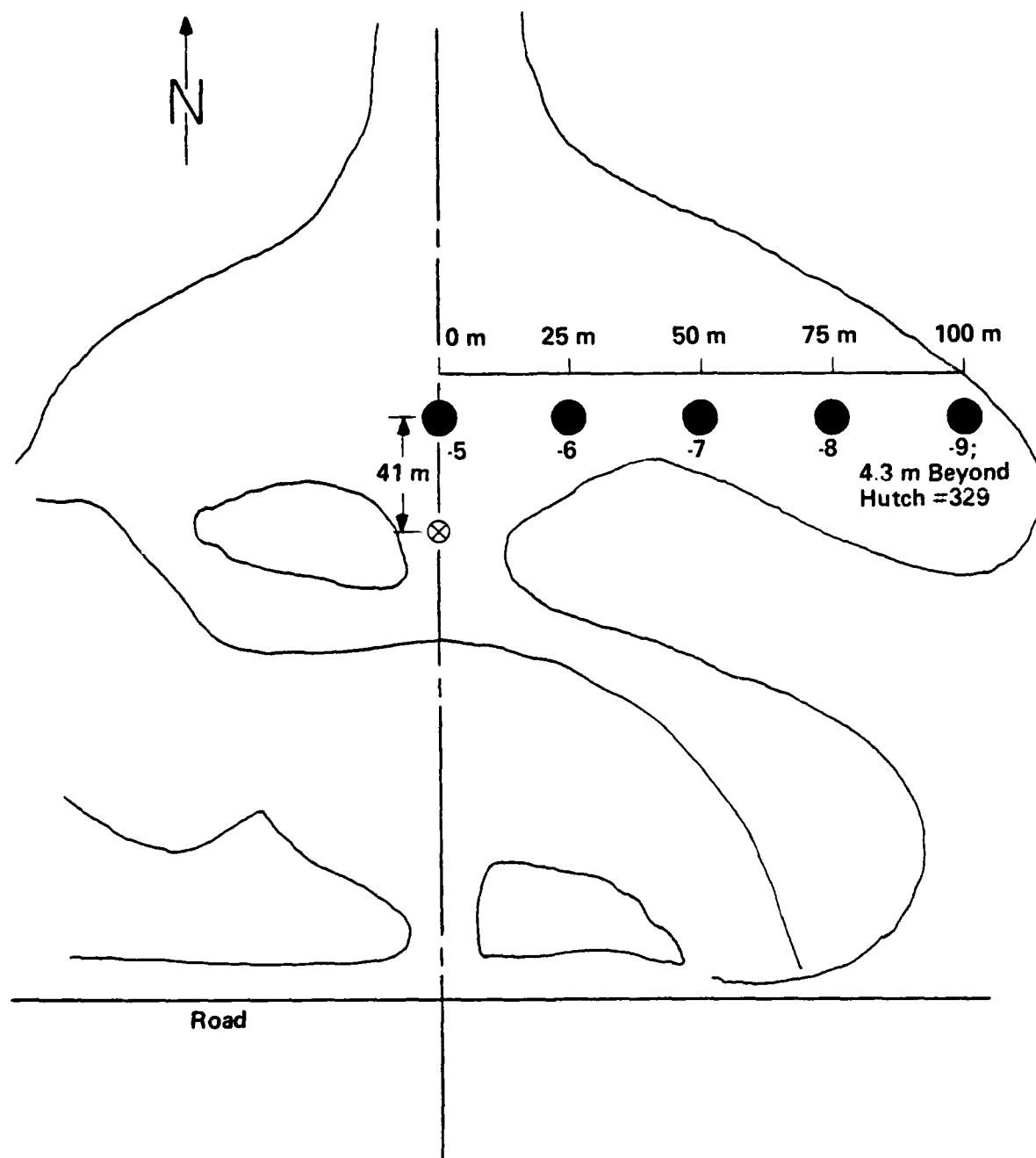


FIGURE A-12. MEASUREMENT POINTS AT CLEVELAND HOMESTEAD; 1T2-5 THROUGH 9.

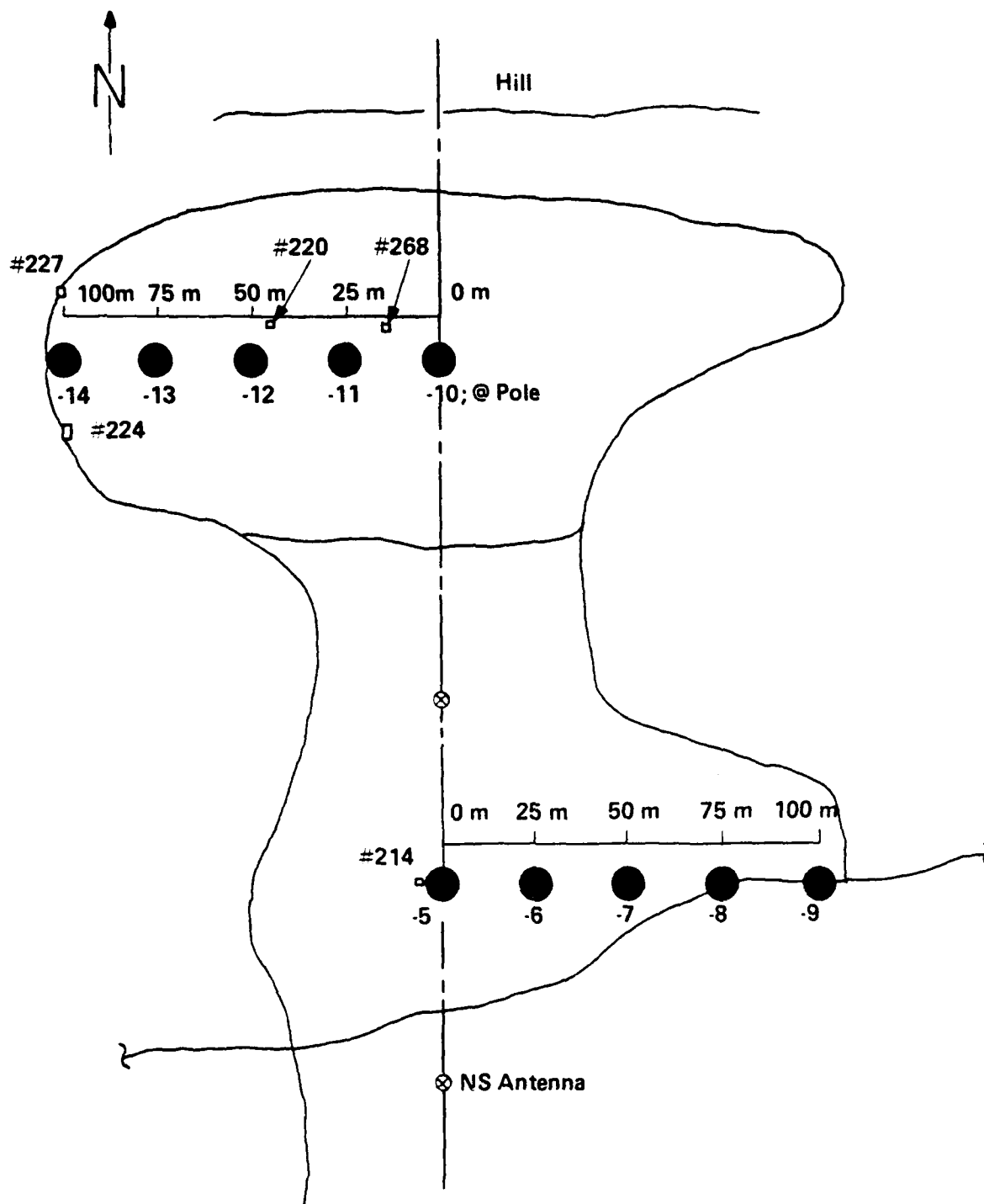


FIGURE A-13. MEASUREMENT POINTS AT NORTH TURNER ROAD; 1T4-5 THROUGH 14.

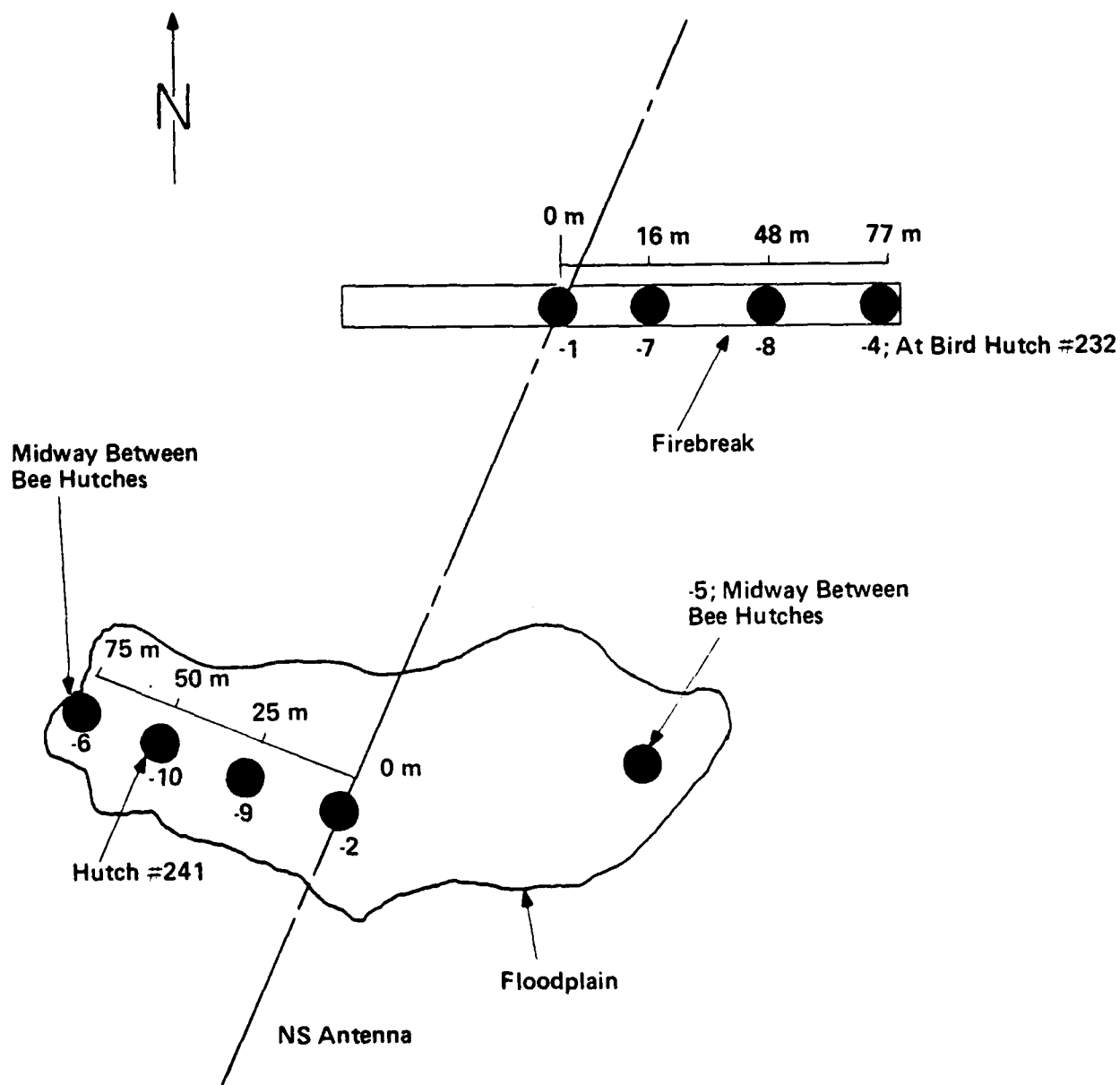


FIGURE A-14. MEASUREMENT POINTS AT FORD RIVER NORTH; 1T5-1, 2, 4, 6, 7, 8, 9, 10.

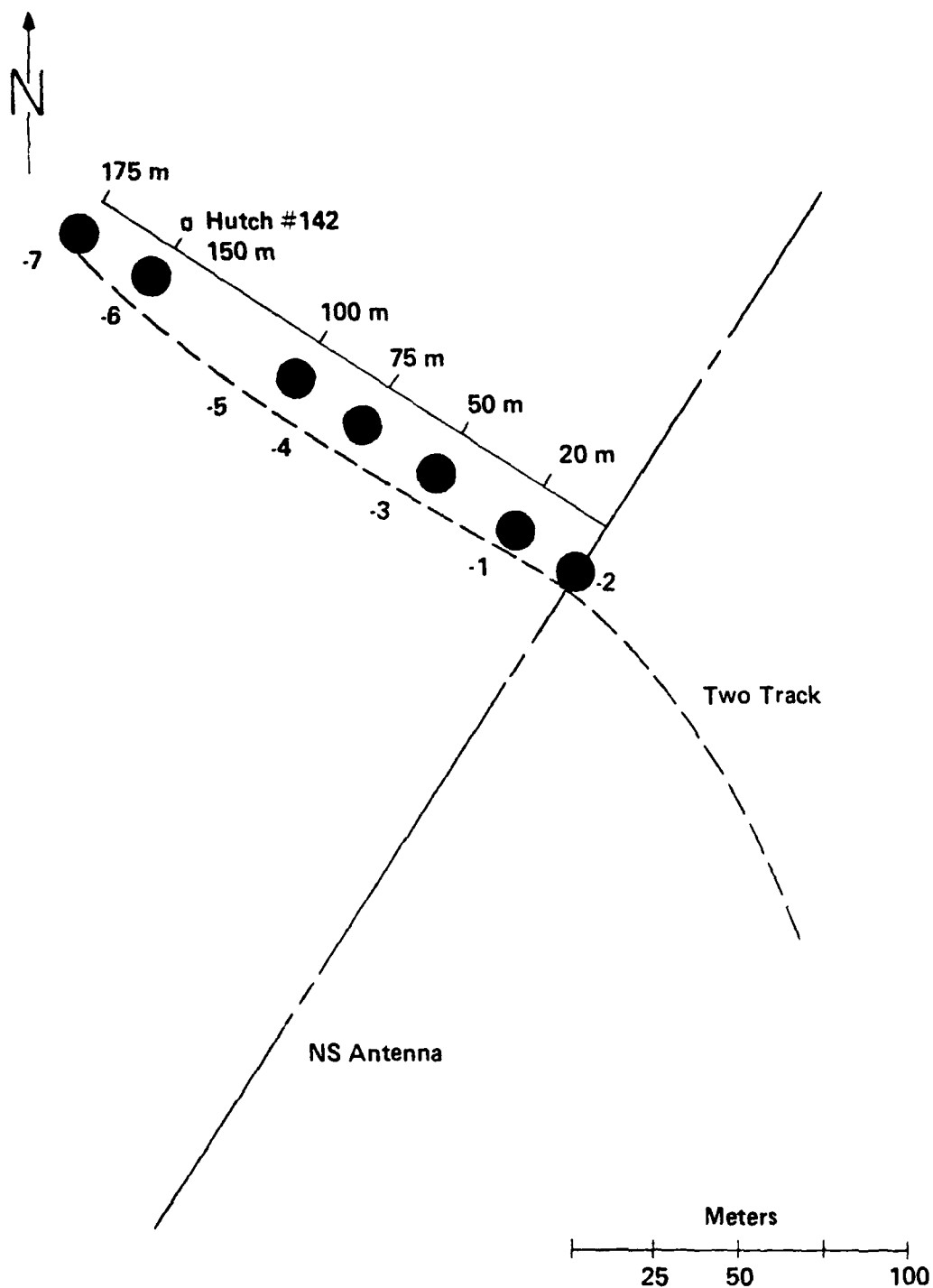


FIGURE A-15. MEASUREMENT POINTS AT FORD RIVER SOUTH NEST BOXES; 1T6-1 THROUGH 7.

EM field measurements for 1987 and previous years are found in Tables A-2 through A-10. Tables A-2, A-3, and A-4 present 60 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Tables A-5, A-6, and A-7 present 76 Hz data for these three fields at 1986 and 1987 MTF operating currents. Tables A-8, A-9, and A-10 present 76 Hz data extrapolated to a full power condition of 150 amperes.

The 1987 60 Hz measurements at test sites showed the same general trends in field magnitudes as were reported in 1986 as the result of 60 Hz signals from power lines coupled onto the ELF antenna elements. That is, the 60 Hz magnetic flux densities increased and the longitudinal electric fields decreased near the antenna wires in comparison to measurements made prior to antenna construction. However, 1987 60 Hz magnetic field levels at test sites were somewhat greater than those measured in 1986. This is likely the result of several factors. For example, the antenna elements were not grounded at the transmitters in 1987 as they were in 1986. The effect of this difference is discussed thoroughly in Section 3.5.2.2 of this report. Other changes in the 60 Hz coupling may result from changes in power line loads or changes in earth conductivity as a function of soil moisture.

The EM fields generated by the 60 Hz current on the antenna wire are localized near the antenna and do not affect the 60 Hz fields at the control sites. All 60 Hz EM field measurements at the control sites for 1987 remained consistent with previous years' measurements.

In 1987, the 76 Hz longitudinal electric field and magnetic flux measured during operation of the east-west antenna element were consistently lower at both test and control sites than those measured in 1986. Because the transverse electric field was often below the sensitivity of the probe, not enough data were available to make a similar comparison for this field.

All 76 Hz EM fields measured in 1987 during operation of the north-south antenna element were consistent with those from 1986, and dominated the fields measured during operation of the east-west antenna element at the test sites.

Changes in the operational status of the MTF between 1986 and 1987 and their relationship to 76 Hz EM field intensities are discussed in Section 3.5.2.3 of this report.

TABLE A-2. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies (page 1 of 2)

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c
1C1-2	-	-	-	--	--
1C1-3	-	-	-	-	-
1C1-4	-	-	-	-	-
1C3-1	-	-	-	-	-
1C3-2	-	-	--	--	--
1C3-3	-	-	-	-	-
1C4-1	-	0.001	-	-	-
1C4-2	-	<0.001	-	--	--
1C4-3	-	<0.001	-	-	--
1C4-4	-	-	-	-	-
1C4-5	-	-	-	-	-
1D3-1	-	-	-	-	-
1C6-1	-	0.001	-	-	-
1C6-3	-	-	-	-	-
1C6-4	-	-	-	-	-
1L1-1	-	-	-	/	/
1L1-2	-	-	-	0.94	0.96
1L1-3	-	-	-	0.79	0.034
1L1-4	-	-	-	0.042	0.047
1T1-1	0.001	-	-	--	--
1T1-3	-	-	-	--	--
1T1-4	-	-	-	--	--
1T1-10	-	-	-	--	--
1T1-12	-	-	-	--	--
1T1-13	-	-	-	--	--
1T1-14	-	-	-	-	-
1T1-15	-	-	-	-	-
1T1-16	-	-	-	-	-
1T1-17	-	-	-	-	-
1T1-18	-	-	-	-	-
1T1-19	-	-	-	-	-
1T1-20	-	-	-	-	-
1T1-21	-	-	-	-	0.086
1T1-22	-	-	-	-	<0.001
1T1-23	-	-	-	-	-
1T1-24	-	-	-	-	-
1T1-25	-	-	-	-	-
1T1-26	-	-	-	-	-
1T1-27	-	-	-	-	-
1T2-1	<0.001	0.001	-	-	--
1T2-2	-	-	-	-	--
1T2-3	-	-	-	-	--
1T2-4	-	-	-	-	--
1T2-5	-	-	-	-	0.198

TABLE A-2. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies (page 2 of 2)

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c
1T2-6	-	-	-	-	0.024
1T2-7	-	-	-	-	0.005
1T2-8	-	-	-	-	0.002
1T2-9	-	-	-	-	<0.001
1D1-1	-	-	-	2.5	2.0
1T4-1	-	<0.001	-	--	--
1T4-3	-	-	-	--	--
1T4-4	-	-	-	--	--
1T4-5	-	-	-	-	0.094
1T4-6	-	-	-	-	0.014
1T4-7	-	-	-	-	0.004
1T4-8	-	-	-	-	<0.001
1T4-9	-	-	-	-	-
1T4-10	-	-	-	-	0.062
1T4-11	-	-	-	-	0.014
1T4-12	-	-	-	-	0.004
1T4-13	-	-	-	-	0.002
1T4-14	-	-	-	-	0.001
1D2-1	-	-	-	-	-
1T5-1	-	<0.001	-	-	0.118
1T5-2	<0.001	<0.001	-	-	0.074
1T5-3	-	-	-	-	--
1T5-4	-	-	-	-	-
1T5-5	-	-	-	-	<0.001
1T5-6	-	-	-	-	<0.001
1T5-7	-	-	-	-	0.019
1T5-8	-	-	-	-	<0.001
1T5-9	-	-	-	-	0.014
1T5-10	-	-	-	-	0.002
1T6-1	<0.001	<0.001,0.001	-	-	0.024
1T6-2	-	-	-	-	0.162
1T6-3	-	-	-	-	0.003
1T6-4	-	-	-	-	0.001
1T6-5	-	-	-	-	0.001
1T6-6	-	-	-	-	0.001
1T6-7	-	-	-	-	<0.001

^a = prior to antenna construction.

^b = antenna elements grounded at transmitter (condition 2).

^c = antenna elements connected to transmitter, transmitter off (condition 9).

- = site measurement point not established.

-- = site measurement point dropped.

- = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.

/ = data not taken.

TABLE A-3. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Small Mammals and Nesting Birds Studies (page 1 of 2)

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c
1C1-2	0.041	0.146	0.056	--	--
1C1-3	-	-	0.128	0.082	0.114
1C1-4	-	-	-	0.117	0.114
1C3-1	0.106	0.26	0.133	0.086	0.118
1C3-2	0.125	0.191	/	--	--
1C3-3	-	-	-	0.074	0.178
1C4-1	-	0.028,0.030	0.045	0.065	0.093
1C4-2	-	0.019,0.023	0.015	--	--
1C4-3	-	0.036,0.065	0.103	0.118	--
1C4-4	-	-	0.009,0.017	0.011	0.011
1C4-5	-	-	-	-	0.037
1D3-1	-	-	-	0.052	0.156
1C6-1	-	0.072	0.095	0.088	0.106
1C6-3	-	-	0.123	0.109	0.141
1C6-4	-	-	0.038	0.007	0.020
1L1-1	-	-	-	/	/
1L1-2	-	-	-	25	23
1L1-3	-	-	-	10.7	1.32
1L1-4	-	-	-	3.9	8.9
1T1-1	0.090	0.091	0.131	--	--
1T1-3	-	0.21	0.179	--	--
1T1-4	-	0.174	0.171	--	--
1T1-10	-	0.097	0.147	--	--
1T1-12	-	-	0.033	--	--
1T1-13	-	-	0.034	--	--
1T1-14	-	-	-	0.102	0.058
1T1-15	-	-	-	0.040	0.029
1T1-16	-	-	-	0.115	0.102
1T1-17	-	-	-	0.118	0.128
1T1-18	-	-	-	0.100	0.104
1T1-19	-	-	-	0.112	0.132
1T1-20	-	-	-	0.118	0.123
1T1-21	-	-	-	0.082	0.082
1T1-22	-	-	-	0.050	0.047
1T1-23	-	-	-	0.037	0.037
1T1-24	-	-	-	0.042	0.058
1T1-25	-	-	-	0.033	0.035
1T1-26	-	-	-	0.022	0.025
1T1-27	-	-	-	0.014	0.021
1T2-1	0.170	0.22	0.197	0.122	--
1T2-2	-	-	-	0.047	--
1T2-3	-	-	-	0.083	--
1T2-4	-	-	-	0.044	--
1T2-5	-	-	-	-	0.074

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TABLE A-3. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Small Mammals and Nesting Birds Studies (page 2 of 2)

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c
1T2-6	-	-	-	-	0.069
1T2-7	-	-	-	-	0.047
1T2-8	-	-	-	-	0.051
1T2-9	-	-	-	-	0.055
1D1-1	-	-	-	9.6	2.4
1T4-1	-	0.178,0.184	0.150	--	--
1T4-3	-	-	0.22	--	--
1T4-4	-	-	0.131	--	--
1T4-5	-	-	-	0.052	0.081
1T4-6	-	-	-	0.104	0.066
1T4-7	-	-	-	0.102	0.090
1T4-8	-	-	-	0.082	0.078
1T4-9	-	-	-	0.088	0.063
1T4-10	-	-	-	-	0.135
1T4-11	-	-	-	-	0.071
1T4-12	-	-	-	-	0.071
1T4-13	-	-	-	-	0.063
1T4-14	-	-	-	-	0.068
1D2-1	-	-	-	0.47	0.160
1T5-1	-	0.24,0.42	0.25	0.115	0.128
1T5-2	0.23	0.26	0.22	0.042	0.092
1T5-3	-	-	-	0.125	--
1T5-4	-	-	-	0.061	0.073
1T5-5	-	-	-	0.077	0.051
1T5-6	-	-	-	0.051	0.034
1T5-7	-	-	-	-	0.107
1T5-8	-	-	-	-	0.099
1T5-9	-	-	-	-	0.080
1T5-10	-	-	-	-	0.036
1T6-1	0.071	0.65-0.88	0.86,0.88	0.23	0.54
1T6-2	-	-	-	-	0.48
1T6-3	-	-	-	-	0.32
1T6-4	-	-	-	-	0.25
1T6-5	-	-	-	-	0.21
1T6-6	-	-	-	-	0.178
1T6-7	-	-	-	-	0.100

^a = prior to antenna construction.

^b = antenna elements grounded at transmitter (condition 2).

^c = antenna elements connected to transmitter, transmitter off (condition 9).

- = site measurement point not established.

-- = site measurement point dropped.

/ = data not taken.

TABLE A-4. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies (page 1 of 2)

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c
1C1-2	<0.001	0.001	0.001	--	--
1C1-3	-	-	0.001	0.001	0.001
1C1-4	-	-	-	0.001	0.001
1C3-1	<0.001	0.002	0.002	0.001	0.001
1C3-2	0.001	0.003	/	--	--
1C3-3	-	-	-	0.001	0.001
1C4-1	-	<0.001,0.001	0.001	0.001	0.002
1C4-2	-	0.002	0.002	--	--
1C4-3	-	<0.001,0.002	<0.001	0.001	--
1C4-4	-	-	0.003	0.002	0.002
1C4-5	-	-	-	-	0.001
1D3-1	-	-	-	0.003	0.002
1C6-1	-	0.003	0.003	0.002	<0.001
1C6-3	-	-	0.003	0.003	0.003
1C6-4	-	-	0.003	0.003	0.004
1L1-1	-	-	-	9.13	/
1L1-2	-	-	-	0.179	0.156
1L1-3	-	-	-	0.080	0.143
1L1-4	-	-	-	0.114	0.118
1T1-1	0.002	0.002	0.002	--	--
1T1-3	-	0.002	0.002	--	--
1T1-4	-	0.002	0.002	--	--
1T1-10	-	0.004	0.003	--	--
1T1-12	-	-	0.004	--	--
1T1-13	-	-	0.005	--	--
1T1-14	-	-	-	0.004	0.003
1T1-15	-	-	-	0.004	0.004
1T1-16	-	-	-	0.009	0.006
1T1-17	-	-	-	0.007	0.009
1T1-18	-	-	-	0.006	0.008
1T1-19	-	-	-	0.001	0.009
1T1-20	-	-	-	0.008	0.011
1T1-21	-	-	-	0.055	0.042
1T1-22	-	-	-	0.012	0.018
1T1-23	-	-	-	0.008	0.011
1T1-24	-	-	-	0.005	0.008
1T1-25	-	-	-	0.005	0.005
1T1-26	-	-	-	0.003	0.004
1T1-27	-	-	-	0.002	0.003
1T2-1	<0.001	0.001	0.001	0.077	--
1T2-2	-	-	-	0.009	--
1T2-3	-	-	-	0.006	--
1T2-4	-	-	-	0.006	--
1T2-5	-	-	-	-	0.050

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TABLE A-4. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies (page 2 of 2)

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c
1T2-6	-	-	-	-	0.018
1T2-7	-	-	-	-	0.009
1T2-8	-	-	-	-	0.006
1T2-9	-	-	-	-	0.005
1D1-1	-	-	-	0.109	0.154
1T4-1	-	0.001	0.001	--	--
1T4-3	-	-	0.001	--	--
1T4-4	-	-	0.001	--	--
1T4-5	-	-	-	0.021	0.060
1T4-6	-	-	-	0.019	0.024
1T4-7	-	-	-	0.011	0.013
1T4-8	-	-	-	0.006	0.008
1T4-9	-	-	-	0.004	0.006
1T4-10	-	-	-	-	0.051
1T4-11	-	-	-	-	0.023
1T4-12	-	-	-	-	0.013
1T4-13	-	-	-	-	0.009
1T4-14	-	-	-	-	0.007
1D2-1	-	-	-	0.004	0.006
1T5-1	-	0.001, 0.002	0.001	0.051	0.071
1T5-2	0.001	0.002	0.001	0.038	0.042
1T5-3	-	-	-	0.007	--
1T5-4	-	-	-	0.006	0.008
1T5-5	-	-	-	0.005	0.019
1T5-6	-	-	-	0.004	0.008
1T5-7	-	-	-	-	0.039
1T5-8	-	-	-	-	0.016
1T5-9	-	-	-	-	0.019
1T5-10	-	-	-	-	0.011
1T6-1	0.002	0.001	0.001	0.020	0.058
1T6-2	-	-	-	-	0.111
1T6-3	-	-	-	-	0.020
1T6-4	-	-	-	-	0.014
1T6-5	-	-	-	-	0.011
1T6-6	-	-	-	-	0.008
1T6-7	-	-	-	-	0.008

^a = prior to antenna construction.

^b = antenna elements grounded at transmitter (condition 2).

^c = antenna elements connected to transmitter, transmitter off (condition 9).

- = site measurement point not established.

-- = site measurement point dropped.

/ = data not taken.

TABLE A-5. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
Measured (M) and Extrapolated (Ex) Data (page 1 of 2)

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M
1C1-3	-	-	-	--	-	-
1C1-4	-	-	-	--	-	-
1C3-1	-	-	-	--	-	-
1C3-3	-	-	-	--	-	-
1C4-1	-	-	-	--	-	-
1C4-3	-	-	-	--	--	--
1C4-4	-	-	-	--	-	-
1C4-5	-	-	-	-	-	-
1D3-1	-	-	-	--	-	-
1C6-1	-	-	-	--	-	-
1C6-3	-	-	-	--	-	-
1C6-4	-	-	-	--	-	-
1L1-1	/	/	/	/	/	/
1L1-2	/	/	/	/	-	-
1L1-3	/	/	/	/	-	-
1L1-4	/	/	/	/	-	-
1T1-14	-	-	-	--	0.004	-
1T1-15	-	-	-	--	0.001	-
1T1-16	-	-	-	--	0.004	-
1T1-17	0.002	-	-	--	0.004	-
1T1-18	0.001	-	-	--	0.004	-
1T1-19	0.002	-	-	--	0.005	-
1T1-20	0.002	-	-	--	0.004	-
1T1-21	1.08	-	-	--	3.6	0.005
1T1-22	0.002	-	-	--	0.005	<0.001
1T1-23	-	-	-	--	0.008	-
1T1-24	-	-	-	--	0.013	-
1T1-25	-	-	-	--	0.019	-
1T1-26	-	-	-	--	0.012	-
1T1-27	-	-	-	--	0.008	-
1T2-1	0.33	-	-	--	--	--
1T2-2	0.003	-	-	--	--	--
1T2-3	0.002	-	-	--	--	--
1T2-4	-	-	-	--	--	--
1T2-5	-	-	-	-	1.28	0.014
1T2-6	-	-	-	-	0.169	0.002
1T2-7	-	-	-	-	0.034	<0.001
1T2-8	-	-	-	-	0.014	-
1T2-9	-	-	-	-	0.008	-
1D1-1	-	-	-	--	-	-

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TABLE A-5. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
Measured (M) and Extrapolated (Ex) Data (page 2 of 2)

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M
1T4-5	0.58	-	-	--	2.1	0.003
1T4-6	0.091	-	-	--	0.31	<0.001
1T4-7	0.022	-	-	--	0.089	-
1T4-8	0.005	-	-	--	0.014	-
1T4-9	0.002	-	-	--	0.008	-
1T4-10	-	-	-	-	1.30	0.001
1T4-11	-	-	-	-	0.30	<0.001
1T4-12	-	-	-	-	0.090	<0.001
1T4-13	-	-	-	-	0.033	<0.001
1T4-14	-	-	-	-	0.015	<0.001
1D2-1	-	-	-	--	-	0.003
1T5-1	0.81	-	-	--	3.1	0.005
1T5-2	0.59	-	-	--	2.9	0.003
1T5-3	0.004	-	-	--	--	--
1T5-4	0.002	-	-	--	0.007	-
1T5-5	0.005	-	-	--	0.019	-
1T5-6	0.009	-	-	--	0.022	-
1T5-7	-	-	-	-	0.54	0.001
1T5-8	-	-	-	-	0.008	<0.001
1T5-9	-	-	-	-	0.44	<0.001
1T5-10	-	-	-	-	0.076	-
1T6-1	0.182	-	-	--	0.48	-
1T6-2	-	-	-	-	3.2	0.005
1T6-3	-	-	-	-	0.042	<0.001
1T6-4	-	-	-	-	0.029	<0.001
1T6-5	-	-	-	-	0.021	<0.001
1T6-6	-	-	-	-	0.019	<0.001
1T6-7	-	-	-	-	0.015	<0.001

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

- = site measurement point not established.

-- = site measurement point dropped.

- = measurement expected to be <0.001 V/m based on
the longitudinal electric field measurement.

-- = data cannot be extrapolated.

/ = data not taken.

TABLE A-6. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Small Mammals and Nesting Birds Studies
Measured (M) and Extrapolated (Ex) Data (page 1 of 2)

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M
1C1-3	0.021	0.003	0.010	0.017	0.082	0.028
1C1-4	/	/	/	/	0.087	0.033
1C3-1	/	/	/	/	0.050	0.025
1C3-3	0.022	0.004	0.012	0.020	0.086	0.032
1C4-1	/	/	/	/	0.005	0.004
1C4-3	/	/	/	/	--	--
1C4-4	<0.001	<0.001	<0.001	--	0.002	0.002
1C4-5	-	-	-	-	0.003	0.002
1D3-1	0.008	0.004	0.005	0.008	0.053	0.019
1C6-1	/	/	/	/	0.004	0.003
1C6-3	0.001	<0.001	0.001	0.002	0.008	0.004
1C6-4	/	/	/	/	0.003	0.002
1L1-1	/	/	/	/	/	/
1L1-2	/	/	/	/	<0.001	<0.001
1L1-3	/	/	/	/	<0.001	<0.001
1L1-4	/	/	/	/	<0.001	<0.001
1T1-14	0.86	0.026	0.021	0.035	3.1	0.069
1T1-15	0.43	0.013	0.015	0.025	1.60	0.051
1T1-16	1.11	0.035	0.035	0.058	4.6	0.133
1T1-17	1.55	0.049	0.053	0.088	6.2	0.139
1T1-18	1.44	0.042	0.050	0.083	5.6	0.166
1T1-19	1.54	0.050	0.053	0.088	6.4	0.142
1T1-20	1.45	0.046	0.043	0.072	6.0	0.142
1T1-21	1.45	0.044	0.009	0.015	7.4	0.026
1T1-22	1.50	0.042	0.009	0.015	4.2	0.021
1T1-23	0.96	0.030	0.003	0.005	2.9	0.017
1T1-24	1.15	0.036	0.010	0.017	4.7	0.020
1T1-25	0.87	0.027	0.062	0.103	2.9	0.019
1T1-26	0.56	0.017	0.004	0.007	2.0	0.014
1T1-27	0.38	0.012	0.004	0.007	1.82	0.015
1T2-1	2.6	0.083	0.21	0.35	--	--
1T2-2	1.27	0.045	0.144	0.24	--	--
1T2-3	1.91	0.073	0.27	0.45	--	--
1T2-4	1.04	0.043	0.155	0.26	--	--
1T2-5	-	-	-	-	8.7	0.77
1T2-6	-	-	-	-	8.5	0.86
1T2-7	-	-	-	-	7.0	0.56
1T2-8	-	-	-	-	7.1	0.66
1T2-9	-	-	-	-	6.2	0.79
1D1-1	0.042	0.28	0.066	0.110	0.23	0.67

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TABLE A-6. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Small Mammals and Nesting Birds Studies
Measured (M) and Extrapolated (Ex) Data (page 2 of 2)

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M
1T4-5	2.1	0.062	0.054	0.090	6.4	0.191
1T4-6	2.5	0.076	0.103	0.172	6.3	0.29
1T4-7	2.2	0.067	0.092	0.153	8.7	0.30
1T4-8	1.91	0.061	0.123	0.21	7.7	0.31
1T4-9	2.1	0.062	0.126	0.21	6.2	0.34
1T4-10	-	-	-	-	12.4	0.29
1T4-11	-	-	-	-	6.4	0.27
1T4-12	-	-	-	-	7.4	0.38
1T4-13	-	-	-	-	5.7	0.33
1T4-14	-	-	-	-	6.7	0.33
1D2-1	0.094	0.44	0.113	0.188	0.41	1.36
1T5-1	2.6	0.079	0.074	0.123	9.7	0.21
1T5-2	1.97	0.064	0.108	0.180	8.2	0.23
1T5-3	3.4	0.099	0.077	0.128	--	--
1T5-4	1.39	0.042	0.061	0.102	5.8	0.21
1T5-5	1.31	0.051	0.101	0.168	5.2	0.33
1T5-6	1.08	0.037	0.070	0.117	3.3	0.21
1T5-7	-	-	-	-	8.4	0.21
1T5-8	-	-	-	-	8.2	0.20
1T5-9	-	-	-	-	7.2	0.29
1T5-10	-	-	-	-	3.4	0.170
1T6-1	5.4	0.159	0.086	0.143	32	0.25
1T6-2	-	-	-	-	27	0.24
1T6-3	-	-	-	-	21	0.144
1T6-4	-	-	-	-	16.3	0.122
1T6-5	-	-	-	-	15.3	0.22
1T6-6	-	-	-	-	11.6	0.132
1T6-7	-	-	-	-	6.0	0.178

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

- = site measurement point not established.

-- = site measurement point dropped.

-- = data cannot be extrapolated.

/ = data not taken.

TABLE A-7. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
Measured (M) and Extrapolated (Ex) Data (page 1 of 2)

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M
1C1-3	<0.001	<0.001	<0.001	--	0.001	<0.001
1C1-4	/	/	/	/	0.001	<0.001
1C3-1	/	/	/	/	0.001	<0.001
1C3-3	<0.001	<0.001	<0.001	--	0.001	<0.001
1C4-1	/	/	/	/	<0.001	<0.001
1C4-3	/	/	/	/	--	--
1C4-4	<0.001	<0.001	<0.001	--	<0.001	<0.001
1C4-5	-	-	-	--	<0.001	<0.001
1D3-1	<0.001	<0.001	<0.001	--	<0.001	<0.001
1C6-1	/	/	/	/	<0.001	<0.001
1C6-3	<0.001	<0.001	<0.001	--	<0.001	<0.001
1C6-4	/	/	/	/	<0.001	<0.001
1L1-1	/	/	/	/	/	/
1L1-2	/	/	/	/	<0.001	<0.001
1L1-3	/	/	/	/	<0.001	<0.001
1L1-4	/	/	/	/	<0.001	<0.001
1T1-14	0.032	0.001	0.001	0.002	0.115	0.003
1T1-15	0.027	0.001	0.001	0.002	0.097	0.003
1T1-16	0.069	0.002	0.001	0.002	0.22	0.002
1T1-17	0.076	0.003	0.001	0.002	0.23	0.001
1T1-18	0.071	0.002	0.001	0.002	0.27	0.002
1T1-19	0.081	0.003	0.001	0.002	0.32	0.002
1T1-20	0.089	0.003	0.001	0.002	0.36	0.002
1T1-21	0.78	0.024	0.004	0.007	2.9	0.005
1T1-22	0.31	0.010	0.002	0.003	1.16	0.016
1T1-23	0.169	0.005	0.001	0.002	0.64	0.003
1T1-24	0.113	0.004	0.001	0.002	0.43	0.003
1T1-25	0.084	0.003	0.007	0.012	0.32	0.003
1T1-26	0.055	0.002	0.001	0.002	0.21	0.002
1T1-27	0.040	0.012	0.001	0.002	0.149	0.002
1T2-1	0.95	0.029	0.006	0.010	--	--
1T2-2	0.105	<0.001	<0.001	--	--	--
1T2-3	0.075	0.002	0.001	0.002	--	--
1T2-4	0.073	0.002	0.001	0.002	--	--
1T2-5	-	-	-	-	3.2	0.005
1T2-6	-	-	-	-	1.23	0.003
1T2-7	-	-	-	-	0.64	0.002
1T2-8	-	-	-	-	0.43	0.003
1T2-9	-	-	-	-	0.32	0.003
1D1-1	<0.001	0.003	0.001	0.002	0.001	0.011

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TABLE A-7. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
Measured (M) and Extrapolated (Ex) Data (page 2 of 2)

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M
1T4-5	0.70	0.022	0.004	0.007	2.9	0.004
1T4-6	0.32	0.010	0.002	0.003	1.21	0.002
1T4-7	0.171	0.005	0.001	0.002	0.66	0.001
1T4-8	0.116	0.003	0.001	0.002	0.43	0.002
1T4-9	0.085	0.003	0.001	0.002	0.34	0.002
1T4-10	-	-	-	-	2.7	0.004
1T4-11	-	-	-	-	0.87	0.003
1T4-12	-	-	-	-	0.64	0.002
1T4-13	-	-	-	-	0.43	0.002
1T4-14	-	-	-	-	0.32	0.002
1D2-1	<0.001	0.003	0.001	0.002	0.002	0.008
1T5-1	0.89	0.029	0.005	0.008	3.6	0.005
1T5-2	0.77	0.024	0.004	0.007	3.1	0.004
1T5-3	0.20	0.006	0.001	0.002	--	--
1T5-4	0.124	0.004	0.001	0.002	0.46	0.001
1T5-5	0.131	0.004	0.001	0.002	0.53	0.001
1T5-6	0.125	0.004	<0.001	--	0.46	0.002
1T5-7	-	-	-	-	1.93	0.002
1T5-8	-	-	-	-	0.75	0.001
1T5-9	-	-	-	-	1.18	0.003
1T5-10	-	-	-	-	0.67	0.002
1T6-1	0.40	0.013	0.002	0.003	1.51	0.004
1T6-2	-	-	-	-	3.9	0.006
1T6-3	-	-	-	-	0.65	0.002
1T6-4	-	-	-	-	0.44	0.002
1T6-5	-	-	-	-	0.34	0.002
1T6-6	-	-	-	-	0.24	0.016
1T6-7	-	-	-	-	0.22	0.002

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

- = site measurement point not established.

-- = site measurement point dropped.

-- = data cannot be extrapolated.

/ = data not taken.

TABLE A-8. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
Data Extrapolated to 150 Ampere Current (page 1 of 2)

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations	
	NS	NEW	SEW	NS	EW
1C1-3	--	--	--	--	--
1C1-4	--	--	--	--	--
1C3-1	--	--	--	--	--
1C3-3	--	--	--	--	--
1C4-1	--	--	--	--	--
1C4-3	--	--	--	--	--
1C4-4	--	--	--	--	--
1C4-5	--	--	--	--	--
1D3-1	--	--	--	--	--
1C6-1	--	--	--	--	--
1C6-3	--	--	--	--	--
1C6-4	--	--	--	--	--
1L1-1	/	/	/	/	/
1L1-2	/	/	/	--	--
1L1-3	/	/	/	--	--
1L1-4	/	/	/	--	--
1T1-14	--	--	--	0.040	--
1T1-15	--	--	--	0.010	--
1T1-16	--	--	--	0.040	--
1T1-17	0.075	--	--	0.040	--
1T1-18	0.038	--	--	0.040	--
1T1-19	0.075	--	--	0.050	--
1T1-20	0.075	--	--	0.040	--
1T1-21	41	--	--	36	0.050
1T1-22	0.075	--	--	0.050	--
1T1-23	--	--	--	0.080	--
1T1-24	--	--	--	0.130	--
1T1-25	--	--	--	0.190	--
1T1-26	--	--	--	0.120	--
1T1-27	--	--	--	0.080	--
1T2-1	12.4	--	--	--	--
1T2-2	0.113	--	--	--	--
1T2-3	0.075	--	--	--	--
1T2-4	--	--	--	--	--
1T2-5	--	--	--	12.8	0.140
1T2-6	--	--	--	1.69	0.020
1T2-7	--	--	--	0.34	--
1T2-8	--	--	--	0.140	--
1T2-9	--	--	--	0.080	--
1D1-1	--	--	--	--	--

TABLE A-8. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Small Mammals and Nesting Birds Studies
Data Extrapolated to 150 Ampere Current (page 2 of 2)

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations	
	NS	NEW	SEW	NS	EW
1T4-5	22	--	--	21	0.030
1T4-6	3.4	--	--	3.1	--
1T4-7	0.83	--	--	0.89	--
1T4-8	0.188	--	--	0.140	--
1T4-9	0.075	--	--	0.080	--
1T4-10	-	-	-	13.0	0.010
1T4-11	-	-	-	3.0	--
1T4-12	-	-	-	0.90	--
1T4-13	-	-	-	0.33	--
1T4-14	--	--	--	0.150	--
1D2-1	--	--	--	--	0.030
1T5-1	30	--	--	31	0.050
1T5-2	22	--	--	29	0.030
1T5-3	0.150	--	--	--	--
1T5-4	0.075	--	--	0.070	--
1T5-5	0.188	--	--	0.190	--
1T5-6	0.34	--	--	0.22	--
1T5-7	-	-	-	5.4	0.010
1T5-8	-	-	-	0.080	--
1T5-9	-	-	-	4.4	--
1T5-10	-	-	-	0.76	--
1T6-1	6.8	--	--	4.8	--
1T6-2	-	-	-	32	0.050
1T6-3	-	-	-	0.42	--
1T6-4	-	-	-	0.29	--
1T6-5	-	-	-	0.21	--
1T6-6	-	-	-	0.190	--
1T6-7	-	-	-	0.150	--

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

- = site measurement point not established.

-- = site measurement point dropped.

- = measurement expected to be <0.001 V/m based on
the longitudinal electric field measurement.

-- = data cannot be extrapolated from measurements lower than
the probe's minimum sensitivity.

/ = data not taken.

TABLE A-9. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Small Mammals and Nesting Birds Studies
Data Extrapolated to 150 Ampere Current (page 1 of 2)

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations	
	NS	NEW	SEW	NS	EW
1C1-3	0.79	0.075	0.25	0.82	0.28
1C1-4	/	/	/	0.87	0.33
1C3-1	/	/	/	0.50	0.25
1C3-3	0.83	0.100	0.30	0.86	0.32
1C4-1	/	/	/	0.050	0.040
1C4-3	/	/	/	--	--
1C4-4	--	--	--	0.020	0.020
1C4-5	-	-	-	0.030	0.020
1D3-1	0.30	0.100	0.125	0.53	0.190
1C6-1	/	/	/	0.040	0.030
1C6-3	0.038	--	0.025	0.080	0.040
1C6-4	/	/	/	0.030	0.020
1L1-1	/	/	/	/	/
1L1-2	/	/	/	--	--
1L1-3	/	/	/	--	--
1L1-4	/	/	/	--	--
1T1-14	32	0.65	0.53	31	0.69
1T1-15	16.1	0.33	0.38	16.0	0.51
1T1-16	42	0.88	0.88	46	1.33
1T1-17	58	1.23	1.33	62	1.39
1T1-18	54	1.05	1.25	56	1.66
1T1-19	58	1.25	1.33	64	1.42
1T1-20	54	1.15	1.08	60	1.42
1T1-21	54	1.10	0.23	74	0.26
1T1-22	56	1.05	0.23	42	0.21
1T1-23	36	0.75	0.075	29	0.170
1T1-24	43	0.90	0.25	47	0.20
1T1-25	33	0.68	1.55	29	0.190
1T1-26	21	0.43	0.100	20	0.140
1T1-27	14.3	0.30	0.100	18.2	0.150
1T2-1	96	2.1	5.3	--	--
1T2-2	48	1.13	3.6	--	--
1T2-3	72	1.83	6.8	--	--
1T2-4	39	1.08	3.9	--	--
1T2-5	-	-	-	87	7.7
1T2-6	-	-	-	85	8.6
1T2-7	-	-	-	70	5.6
1T2-8	-	-	-	71	6.6
1T2-9	-	-	-	62	7.9
1D1-1	1.58	7.0	1.65	2.3	6.7

TABLE A-9. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Small Mammals and Nesting Birds Studies
Data Extrapolated to 150 Ampere Current (page 2 of 2)

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations	
	NS	NEW	SEW	NS	EW
1T4-5	79	1.55	1.35	64	1.91
1T4-6	94	1.90	2.6	63	2.9
1T4-7	83	1.68	2.3	87	3.0
1T4-8	72	1.53	3.1	77	3.1
1T4-9	79	1.55	3.2	62	3.4
1T4-10	-	-	-	124	2.9
1T4-11	-	-	-	64	2.7
1T4-12	-	-	-	74	3.8
1T4-13	-	-	-	57	3.3
1T4-14	-	-	-	67	3.3
1D2-1	3.5	11.0	2.8	4.1	13.6
1T5-1	98	1.98	1.85	97	2.1
1T5-2	74	1.60	2.7	82	2.3
1T5-3	128	2.5	1.93	--	--
1T5-4	52	1.05	1.53	58	2.1
1T5-5	49	1.28	2.5	52	3.3
1T5-6	41	0.93	1.75	33	2.1
1T5-7	-	-	-	84	2.1
1T5-8	-	-	-	82	2.0
1T5-9	-	-	-	72	2.9
1T5-10	-	-	-	34	1.70
1T6-1	200	4.0	2.2	320	2.5
1T6-2	-	-	-	270	2.4
1T6-3	-	-	-	210	1.44
1T6-4	-	-	-	163	1.22
1T6-5	-	-	-	153	2.2
1T6-6	-	-	-	116	1.32
1T6-7	-	-	-	60	1.78

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

- = site measurement point not established.

-- = site measurement point dropped.

-- = data cannot be extrapolated from measurements lower than
the probe's minimum sensitivity.

/ = data not taken.

TABLE A-10. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
Data Extrapolated to 150 Ampere Current (page 1 of 2)

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations	
	NS	NEW	SEW	NS	EW
1C1-3	--	--	--	0.010	--
1C1-4	/	/	/	0.010	--
1C3-1	/	/	/	0.010	--
1C3-3	--	--	--	0.010	--
1C4-1	/	/	/	--	--
1C4-3	/	/	/	--	--
1C4-4	--	--	--	--	--
1C4-5	-	-	-	--	--
1C6-1	/	/	/	--	--
1C6-3	/	/	/	--	--
1C6-4	/	/	/	--	--
1D1-1	--	0.075	0.025	0.010	0.110
1D2-1	--	0.075	0.025	0.020	0.080
1D3-1	--	--	--	--	--
1L1-1	/	/	/	/	/
1L1-2	/	/	/	--	--
1L1-3	/	/	/	--	--
1L1-4	/	/	/	--	--
1T1-14	1.20	0.025	0.025	1.15	0.030
1T1-15	1.01	0.025	0.025	0.97	0.030
1T1-16	2.6	0.050	0.025	2.2	0.020
1T1-17	2.9	0.075	0.025	2.3	0.010
1T1-18	2.7	0.050	0.025	2.7	0.020
1T1-19	3.0	0.075	0.025	3.2	0.020
1T1-20	3.3	0.075	0.025	3.6	0.020
1T1-21	29	0.60	0.100	29	0.050
1T1-22	11.6	0.25	0.050	11.6	0.160
1T1-23	6.3	0.125	0.025	6.4	0.030
1T1-24	4.2	0.100	0.025	4.3	0.030
1T1-25	3.2	0.075	0.175	3.2	0.030
1T1-26	2.1	0.050	0.025	2.1	0.020
1T1-27	1.50	0.30	0.025	1.49	0.020
1T2-1	36	0.73	0.150	--	--
1T2-2	3.9	--	--	--	--
1T2-3	2.8	0.050	0.025	--	--
1T2-4	2.7	0.050	0.025	--	--
1T2-5	-	-	-	32	--
0.0501T2-6	-	-	-	12.3	0.030
1T2-7	-	-	-	6.4	0.020
1T2-8	-	-	-	4.3	0.030
1T2-9	-	-	-	3.2	0.030

TABLE A-10. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Small Mammals and Nesting Birds Studies
Data Extrapolated to 150 Ampere Current (page 2 of 2)

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations	
	NS	NEW	SEW	NS	EW
1T4-5	26	0.55	0.100	29	0.040
1T4-6	12.0	0.25	0.050	12.1	0.020
1T4-7	6.4	0.125	0.025	6.6	0.010
1T4-8	4.4	0.075	0.025	4.3	0.020
1T4-9	3.2	0.075	0.025	3.4	0.020
1T4-10	-	-	-	27	0.040
1T4-11	-	-	-	8.7	0.030
1T4-12	-	-	-	6.4	0.020
1T4-13	-	-	-	4.3	0.020
1T4-14	-	-	-	3.2	0.020
1T5-1	33	0.73	0.125	36	0.050
1T5-2	29	0.60	0.100	31	0.040
1T5-3	7.5	0.150	0.025	--	--
1T5-4	4.7	0.100	0.025	4.6	0.010
1T5-5	4.9	0.100	0.025	5.3	0.010
1T5-6	4.7	0.100	--	4.6	0.020
1T5-7	-	-	-	19.3	0.020
1T5-8	-	-	-	7.5	0.010
1T5-9	-	-	-	11.8	0.030
1T5-10	-	-	-	6.7	0.020
1T6-1	15.0	0.33	0.050	15.1	0.040
1T6-2	-	-	-	39	0.060
1T6-3	-	-	-	6.5	0.020
1T6-4	-	-	-	4.4	0.020
1T6-5	-	-	-	3.4	0.020
1T6-6	-	-	-	2.4	0.160
1T6-7	-	-	-	2.2	0.020

NS = north-south antenna element.
 NEW = northern east-west antenna element.
 SEW = southern east-west antenna element.
 EW = both east-west antenna elements (operational configuration).
 - = site measurement point not established.
 -- = site measurement point dropped.
 -- = data cannot be extrapolated from measurements lower than
 the probe's minimum sensitivity.
 / = data not taken.

Plots of 60 and 76 Hz EM field gradients across nest box sites at Pirlot Road, Cleveland Homestead, North Turner Road, and Ford River North and South are given in Figures A-16 through A-30. As shown, the magnetic fields generated by the 60 Hz current on the antenna wire are localized near the antenna and fall off rapidly and uniformly with distance. The longitudinal electric fields also decrease with distance, but are much less uniform, and reflect local changes in ground elevation and soil conductivity. The 76 Hz EM fields measured at a 15 ampere antenna current are typically 10 to 100 times greater than the 60 Hz fields. The gradient shape, however, closely follows that of the corresponding 60 Hz field. The 76 Hz transverse electric field consistently displayed an exponential decay along the transect length at each site. The 60 Hz transverse electric fields were too low to be detected at several measurement points and gradient plots were therefore not constructed. Using the gradient plot figures, an estimate of the EM exposure at any nest box can be determined if the perpendicular distance from the box to the antenna wire is known.

Field measurements were made at the release points for the Cleveland Homestead, North Turner Road, and Panola Plains study sites. The EM field environment across the flight path can be estimated using Figures A-31 and A-32. The locations of the bird flight paths and the ELF antenna are shown relative to positions of high voltage 60 Hz transmission lines (Figure A-31) and 60 Hz power distribution lines (Figure A-32). The fields generated by the distribution lines are of magnitudes similar to those that will be generated by the ELF antenna when operating at the intended 150 ampere current level. The fields produced by the transmission lines can be considerably higher, depending on operating conditions. The electric field generated by a transmission line may be as much as 100 times greater than that of the ELF antenna. The magnetic flux generated by a transmission line is dependent on the load current, and may be several times greater than that of the ELF antenna.

The 60 Hz magnetic fields at the animal holding facility/laboratory site (1L1) were discussed in Section 2.1 of this report. These fields are 10 to 100 times higher than those at the treatment and control trapping sites. Power and shelter requirements for the laboratory test equipment make it difficult to find a more suitable location for the laboratory. Exposure of the animals to high 60 Hz fields, however, can be minimized by sheltering them

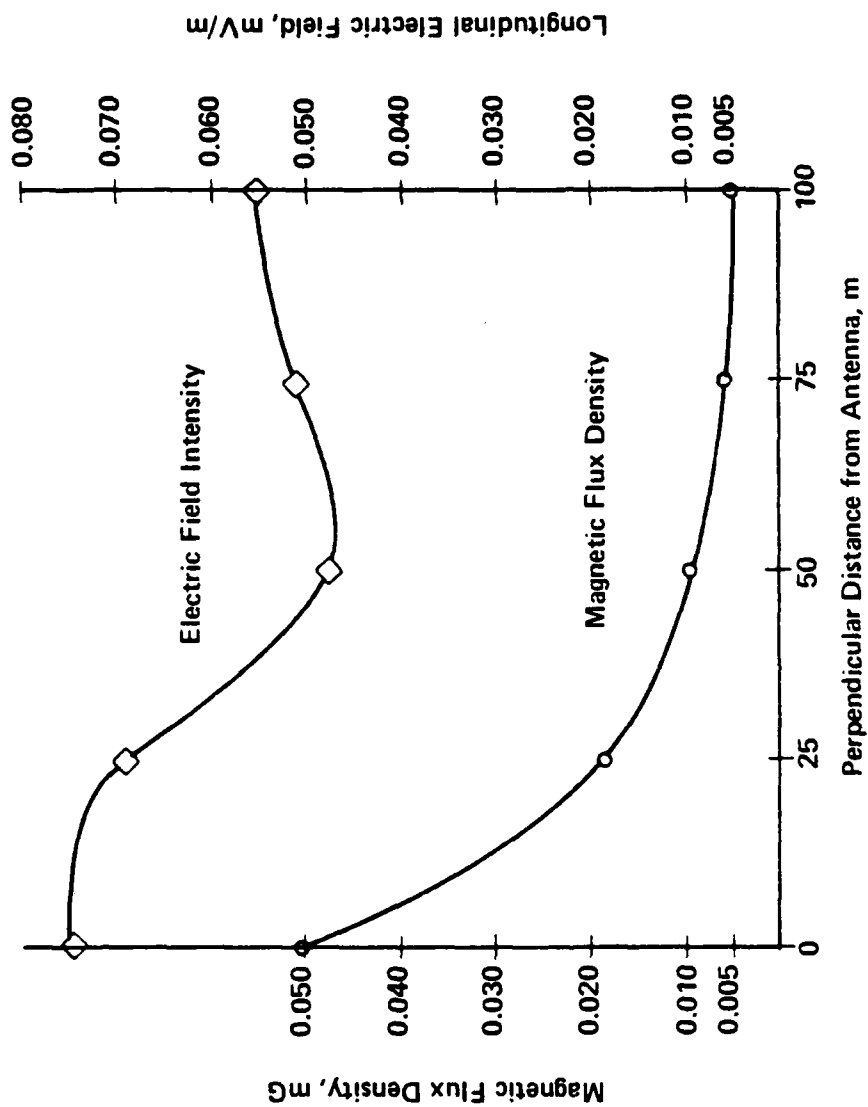


FIGURE A-17. 1987 60 Hz EM FIELD GRADIENT PLOTS FOR CLEVELAND HOMESTEAD NEST BOXES; 1T2 - 5 THROUGH 9.

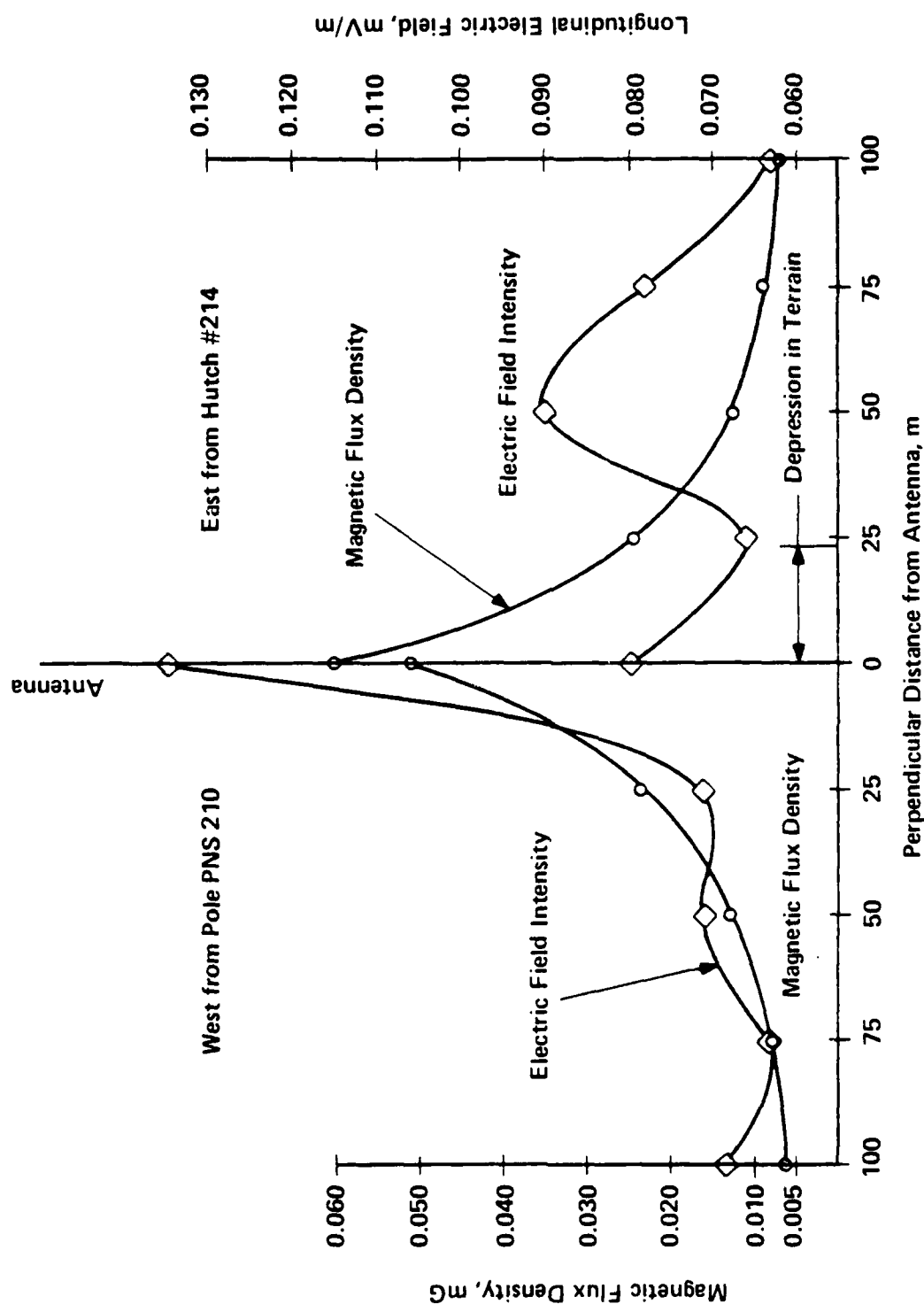


FIGURE A-18. 1987 60 Hz EM FIELD GRADIENT PLOTS FOR NORTH TURNER ROAD NEST BOXES;
1T4 - 5 THROUGH 9 (EAST) AND 1T4 - 10 THROUGH 14 (WEST).

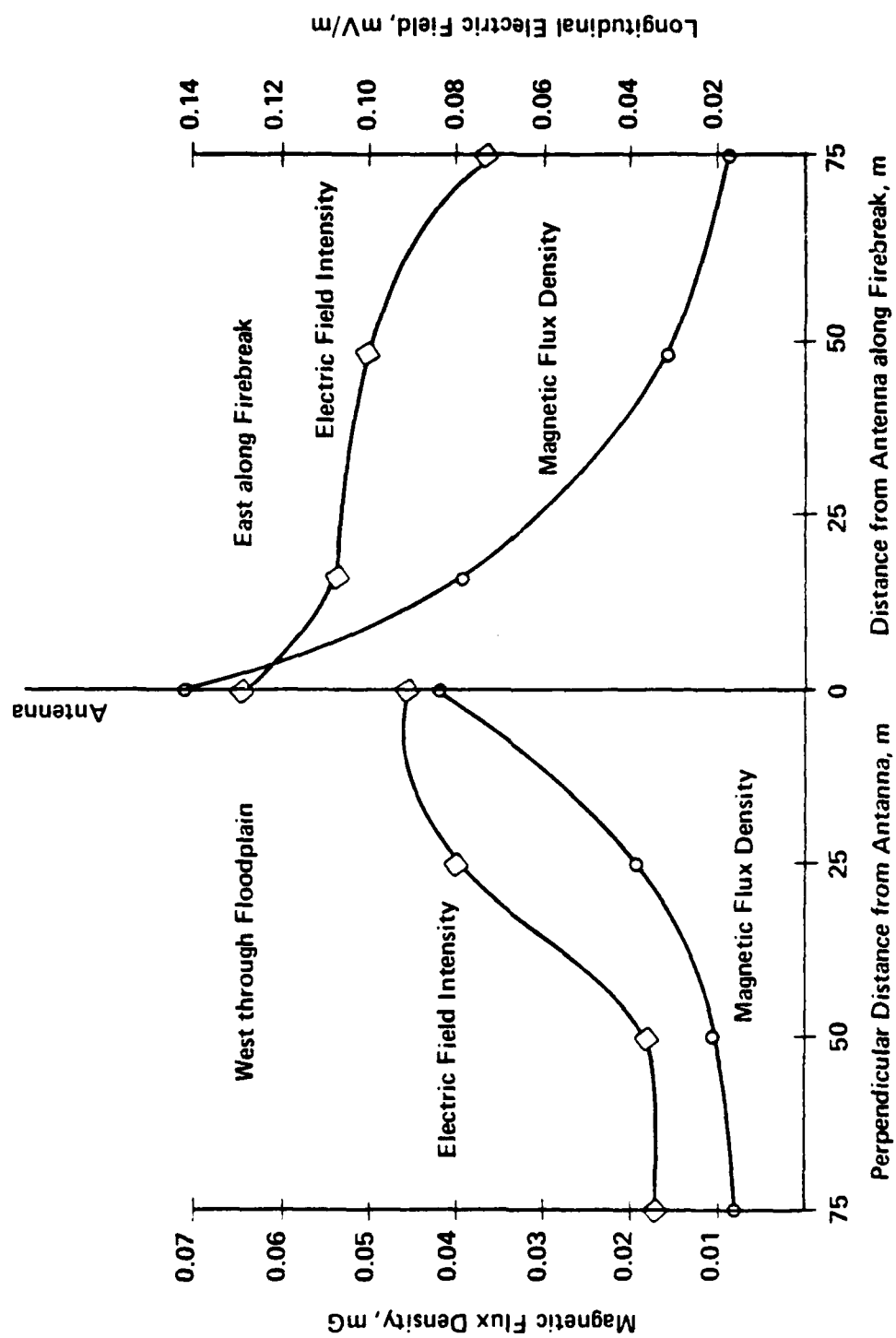


FIGURE A-19. 1987 60 Hz EM FIELD GRADIENT PLOTS FOR FORD RIVER NORTH NEST BOXES;
1T5 - 1, 7, 8, 4 (EAST) AND 1T5 - 2, 9, 10, 6 (WEST).

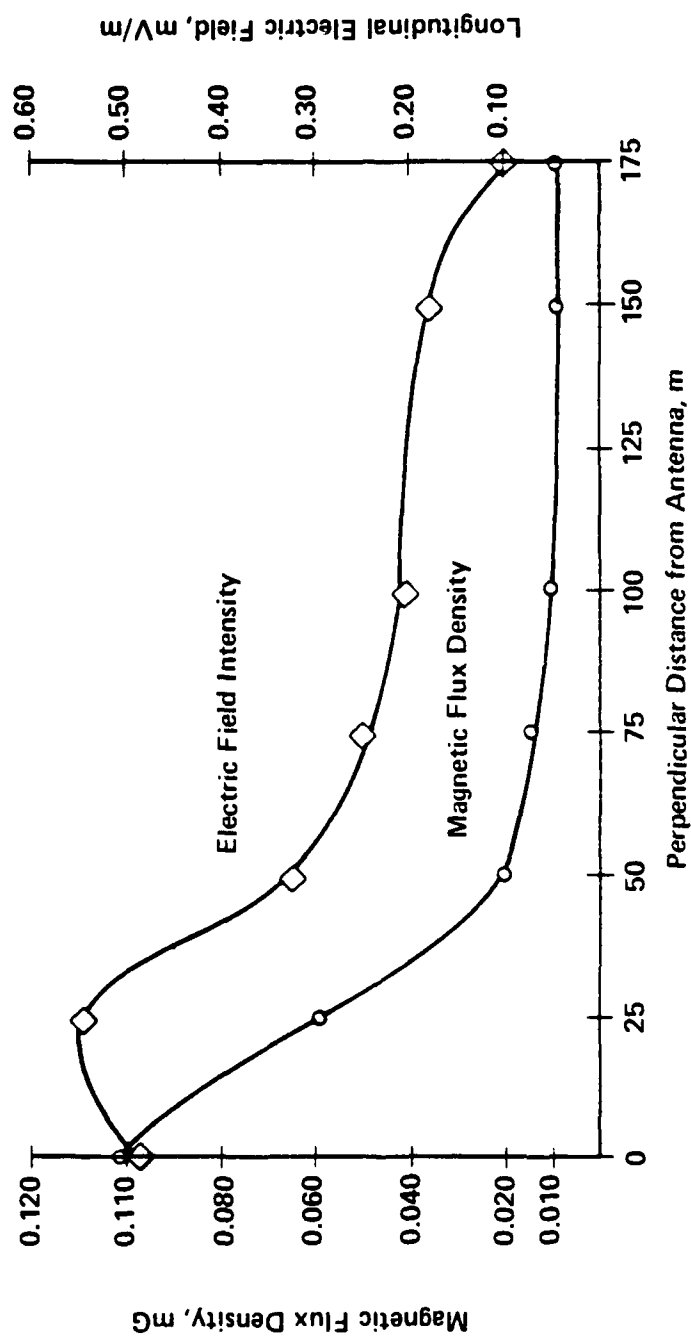


FIGURE A-20. 1987 60 Hz EM FIELD GRADIENT PLOTS FOR FORD RIVER SOUTH NEST BOXES;
1T6-2, 1, 3, 4, 5, 6, 7.

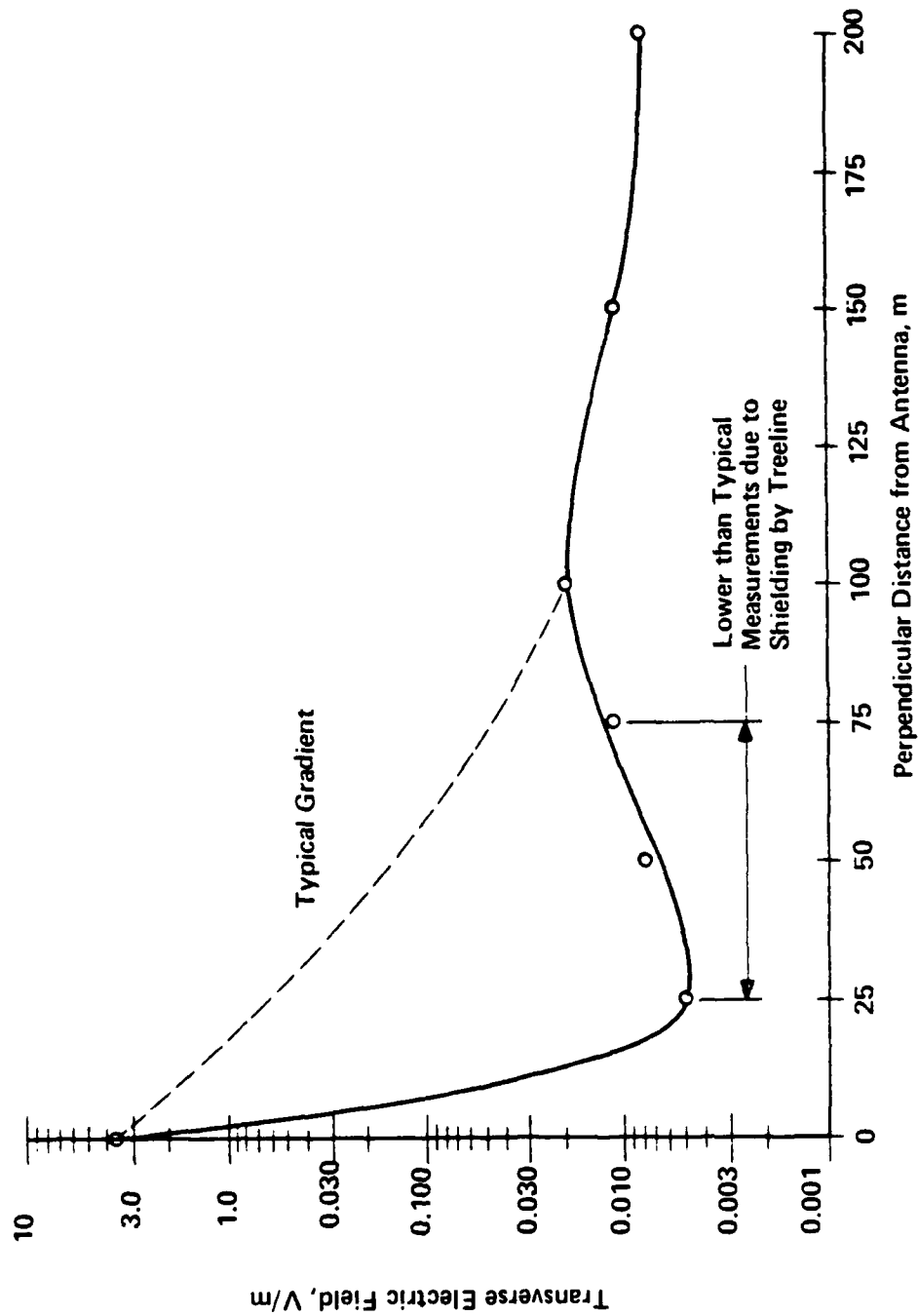


FIGURE A-21. 1987 76 Hz EM FIELD GRADIENT PLOT FOR PILOT ROAD NEST BOXES; 1T1 - 21 THROUGH 27 (15 AMP ANTENNA CURRENT).

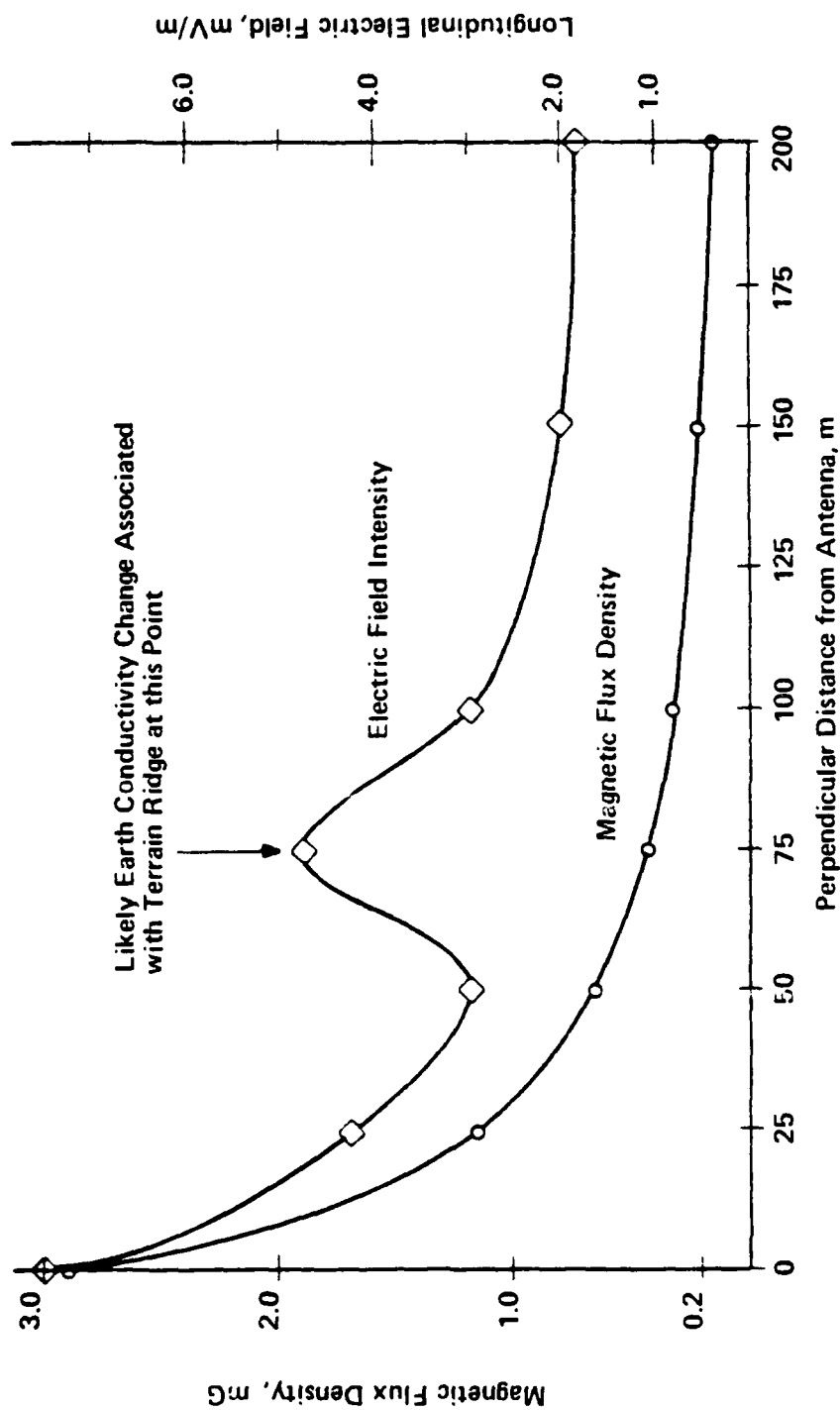


FIGURE A-22. 1987 76 Hz EM FIELD GRADIENT PLOTS FOR PIRLOT ROAD NEST BOXES; 1T1 - 21 THROUGH 27. (15 AMP ANTENNA CURRENT).

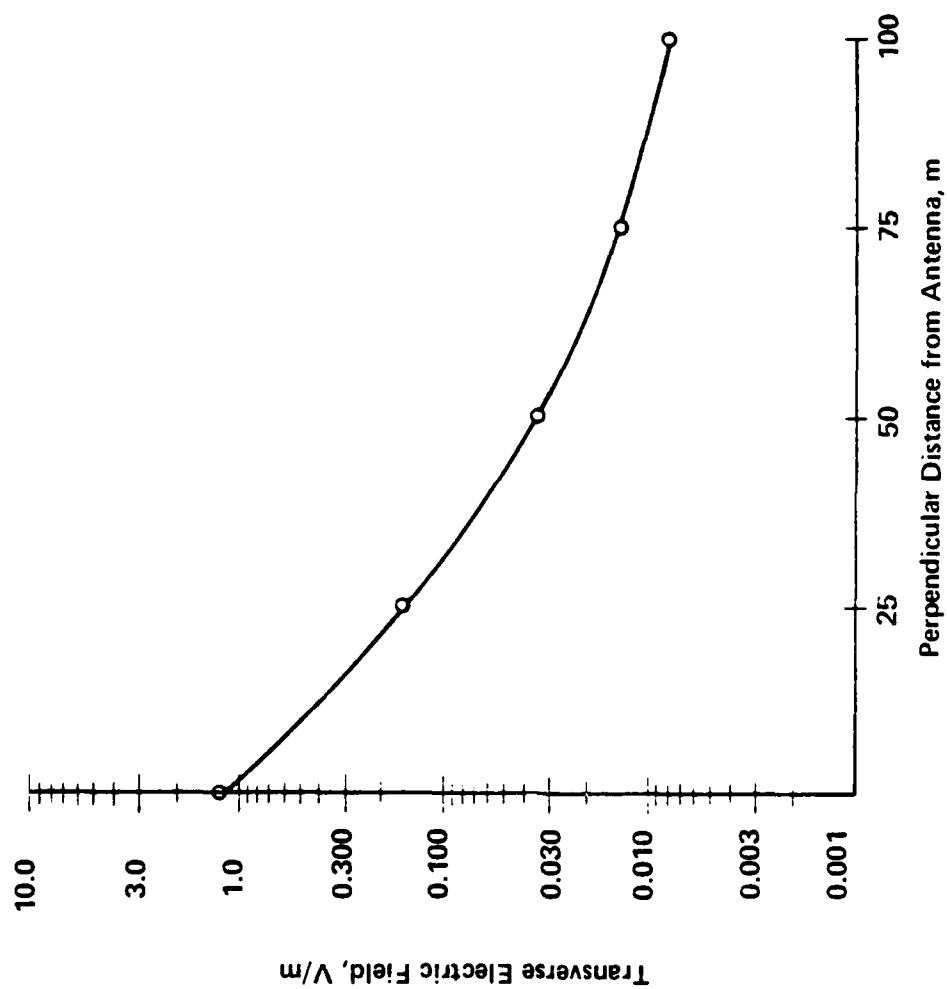


FIGURE A-23. 1987 76 Hz EM FIELD GRADIENT PLOT FOR CLEVELAND HOMESTEAD NEST BOXES;
1T2 - 5 THROUGH 9 (15 AMP ANTENNA CURRENT).

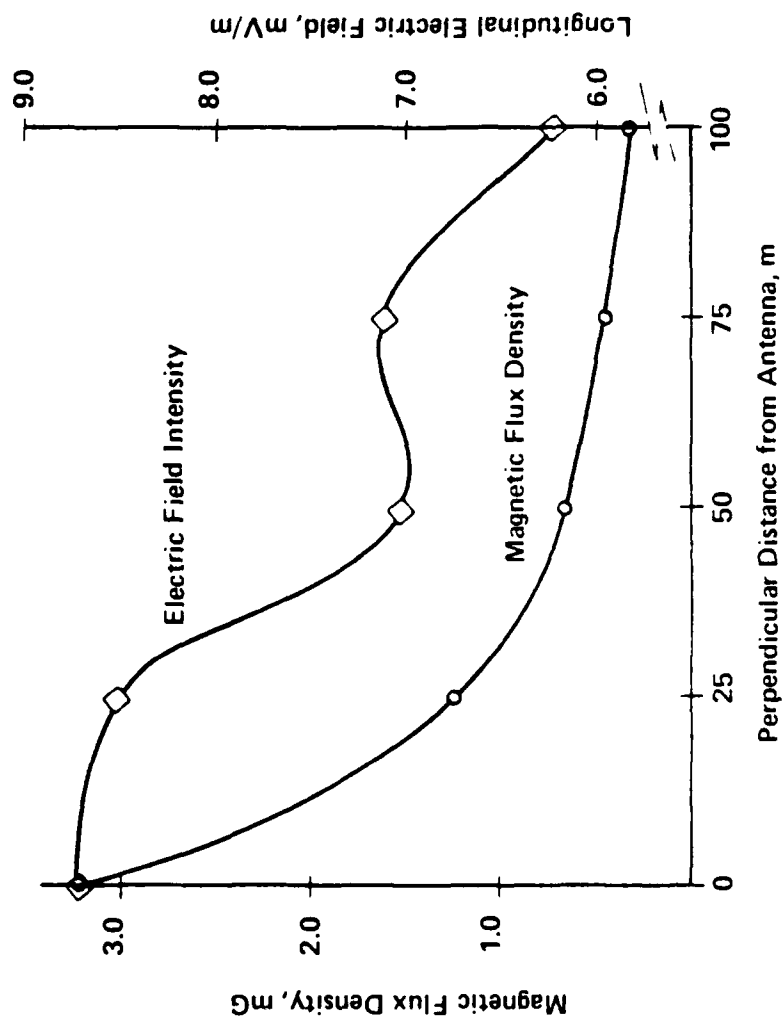


FIGURE A-24. 1987 76 Hz EM FIELD GRADIENT PLOTS FOR CLEVELAND HOMESTEAD NEST BOXES; 1T2 - 5 THROUGH 9 (15 AMP ANTENNA CURRENT).

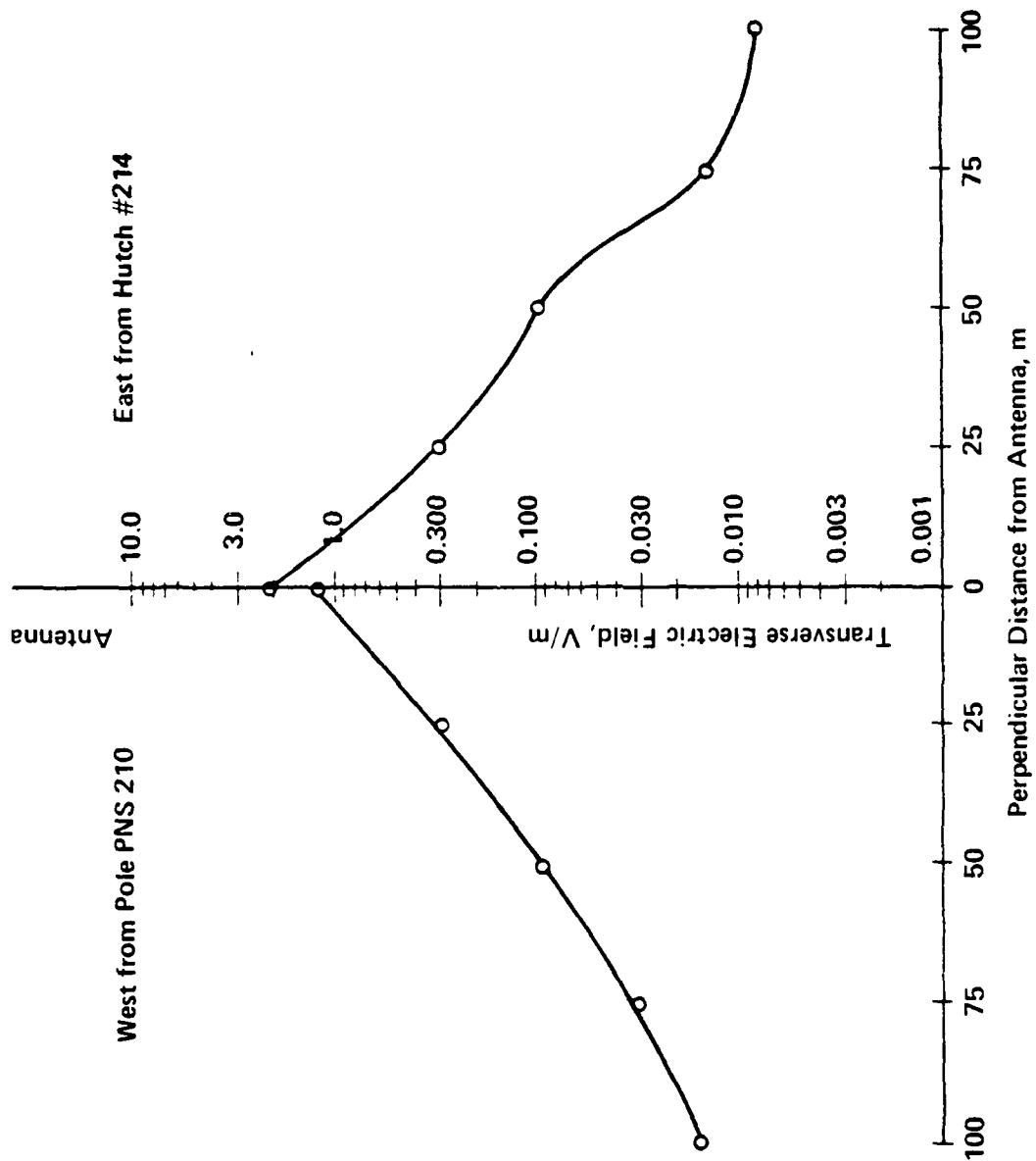


Figure A-25. 1987 76 Hz EM field gradient plots for North Turner Road Nest Boxes; 1T4 - 5 through 9 (East) and 1T4 - 10 through 14 (West) (15 AMP ANTENNA CURRENT).

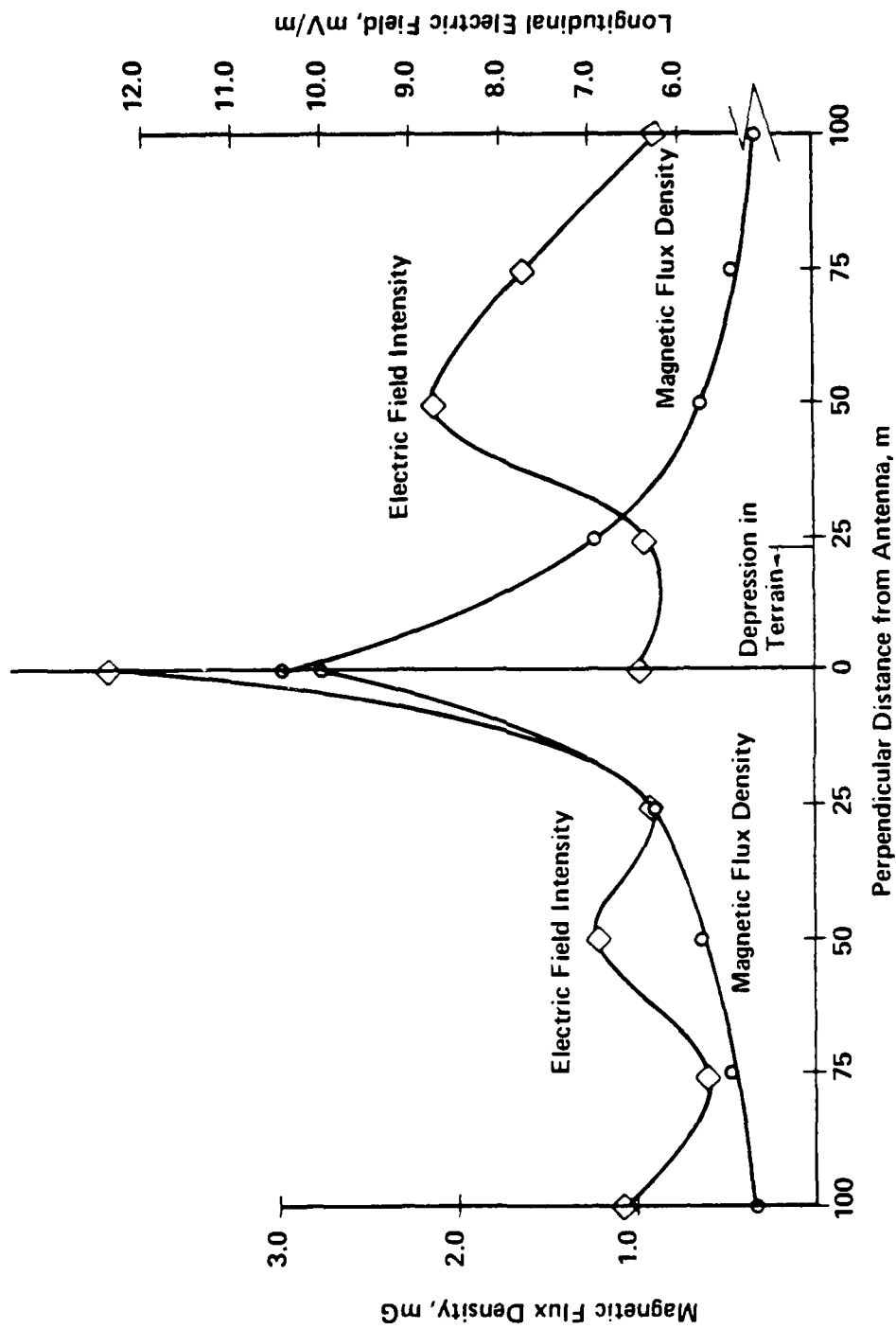


FIGURE A-26. 1987 76 Hz EM FIELD GRADIENT PLOTS FOR NORTH TURNER ROAD NEST BOXES; 1T4-5 THROUGH 9 (EAST) AND 1T4-10 THROUGH 14 (WEST) (15 AMP CURRENT).

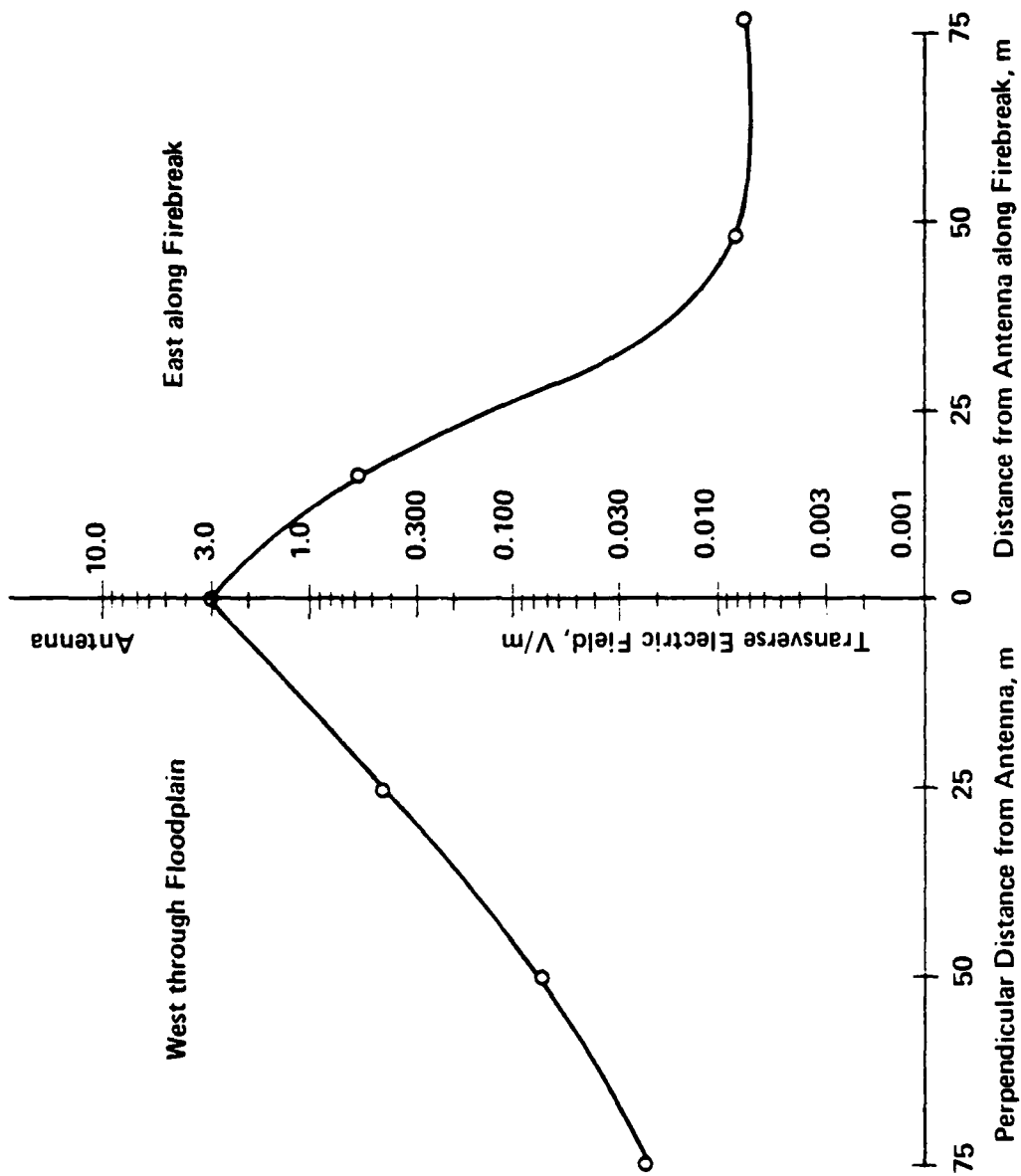


FIGURE A-27. 1987 76 Hz EM FIELD GRADIENT PLOTS FOR FORD RIVER NORTH NEST BOXES; 1T5 - 1, 7, 8, 4 (EAST) AND 1T5 - 2, 9, 10, 6 (WEST) (15 AMP ANTENNA CURRENT).

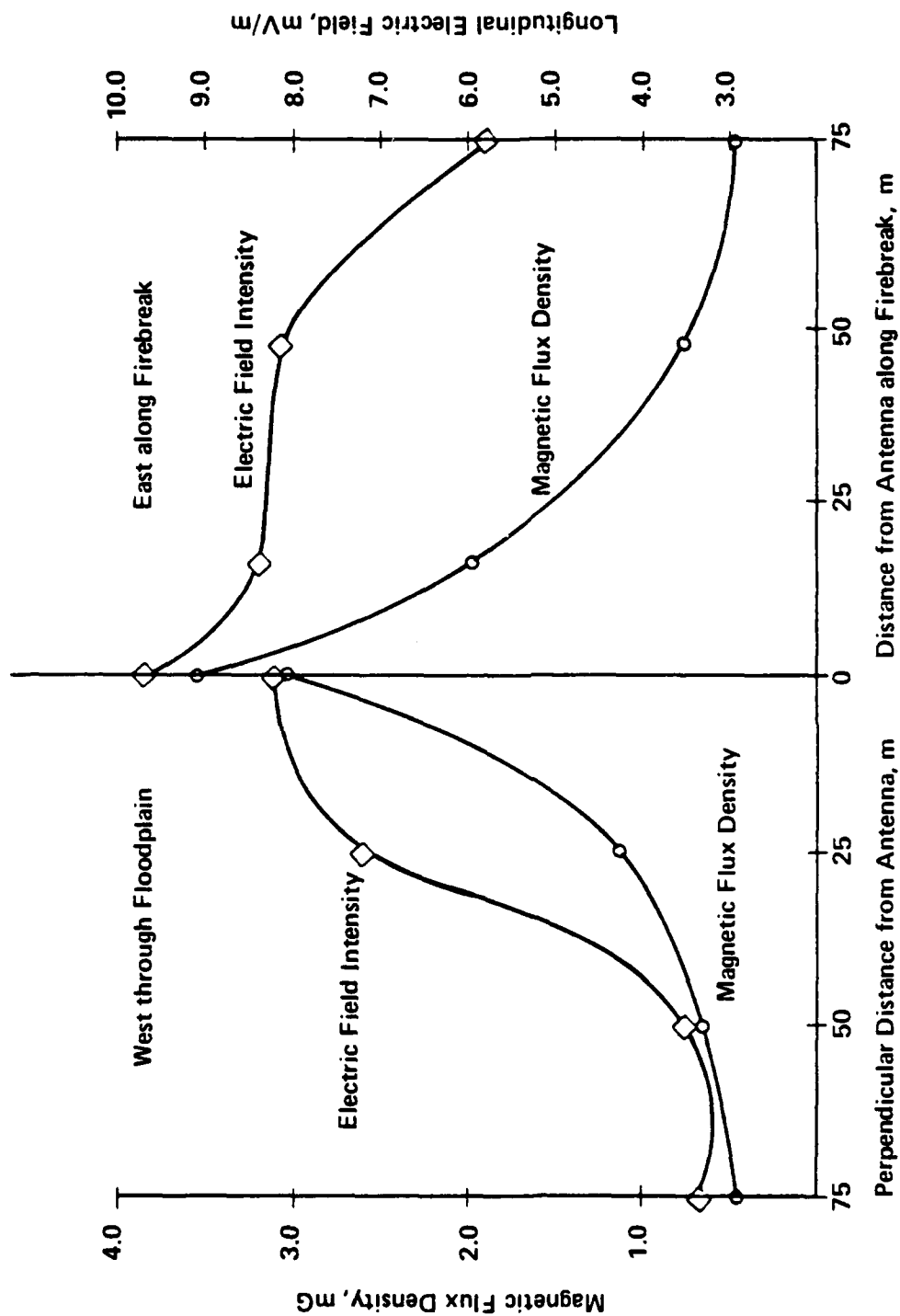


FIGURE A-28. 1987 76 Hz EM FIELD GRADIENT PLOTS FOR FORD RIVER NORTH NEST BOXES;
1T5 - 1, 7, 8, 4 (EAST) AND 1T5 - 2, 9, 10 (WEST) (15 AMP ANTENNA CURRENT).

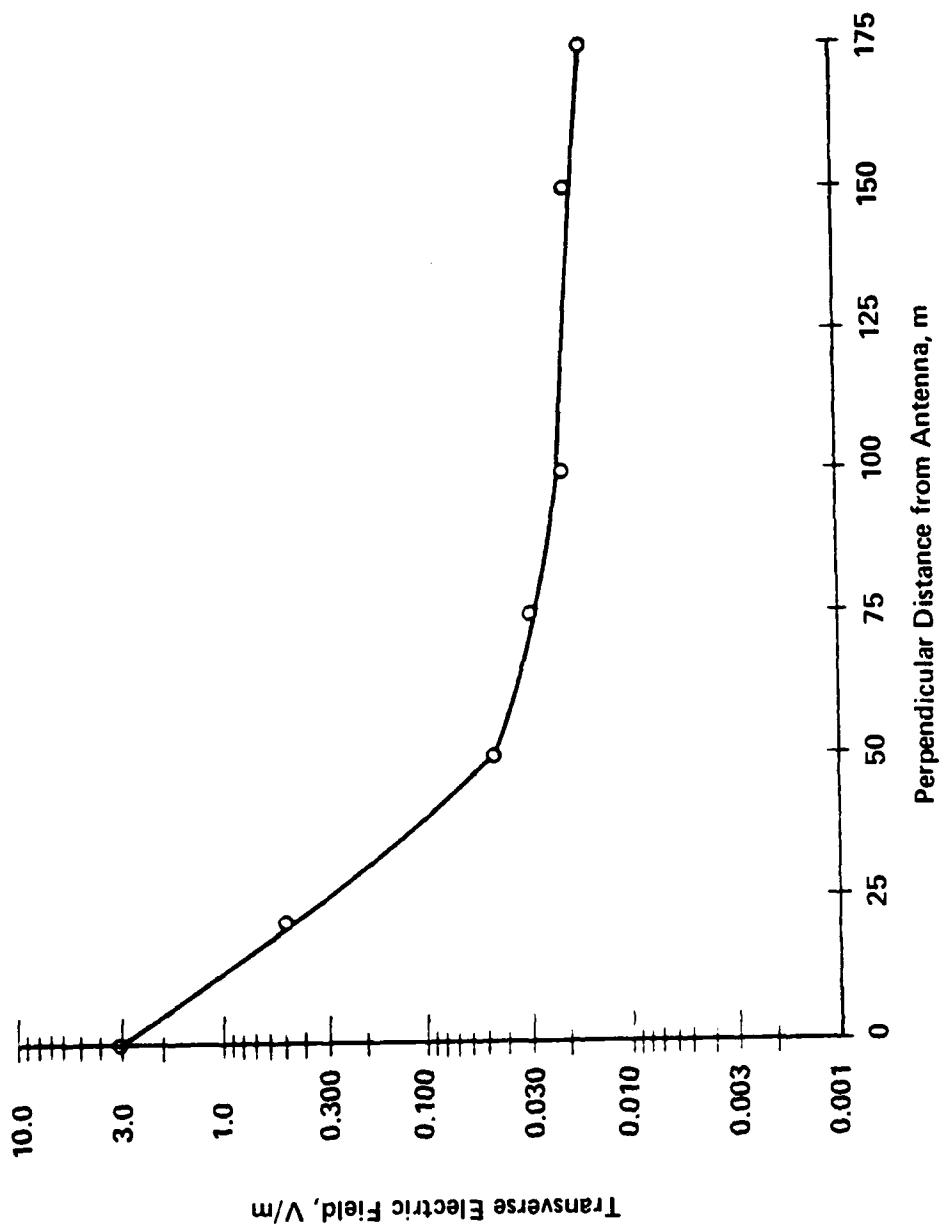


FIGURE A-29. 1987 76 Hz EM FIELD GRADIENT PLOTS FOR FORD RIVER SOUTH NEST BOXES;
1T6 - 2, 1, 3, 4, 5, 6, 7 (15 AMP ANTENNA CURRENT).

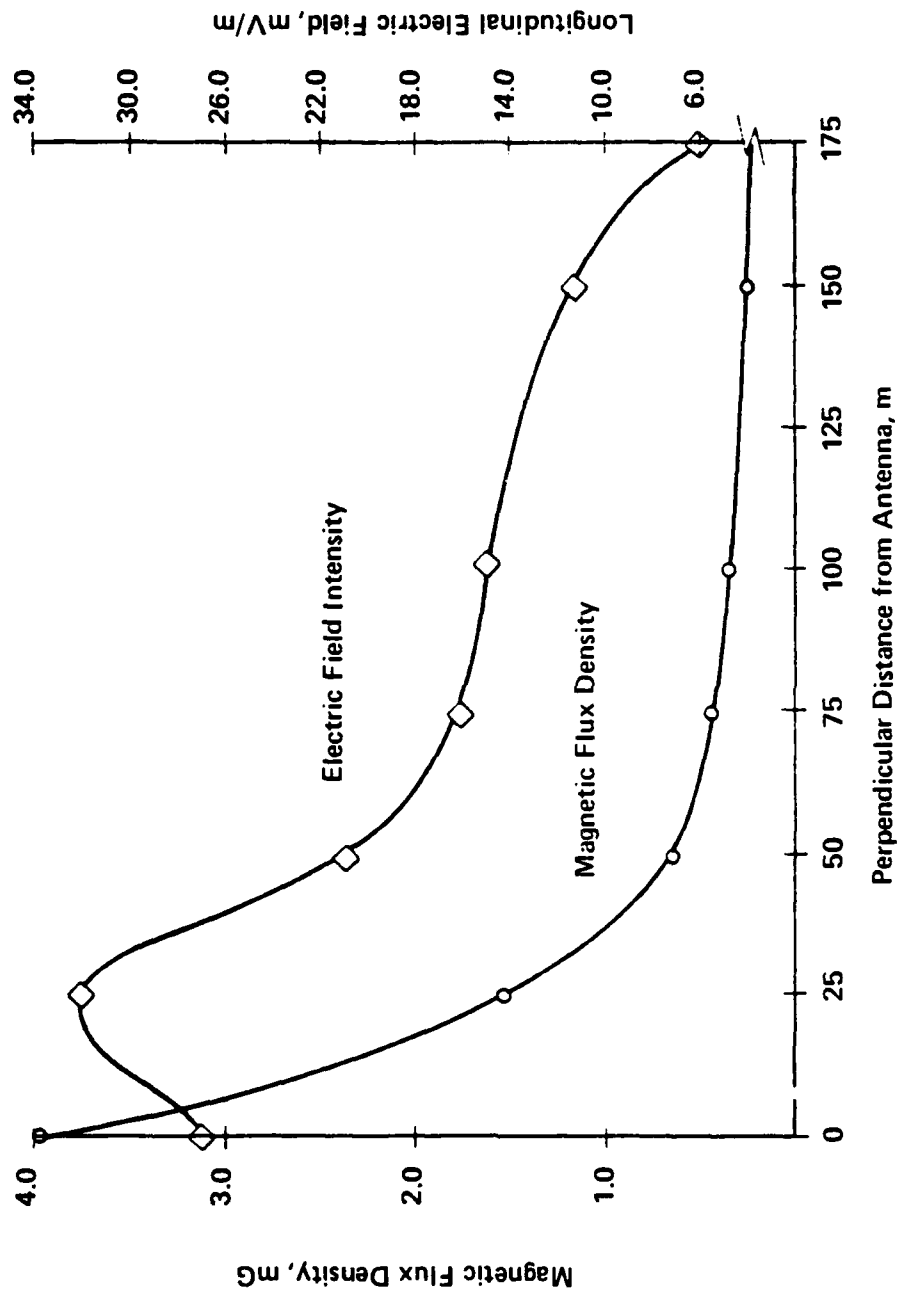


FIGURE A-30. 1987 76 Hz EM FIELD GRADIENT PLOTS FOR FORD RIVER SOUTH NEST BOXES;
1T6-2, 1, 3, 4, 5, 6, 7 (15 AMP ANTENNA CURRENT).

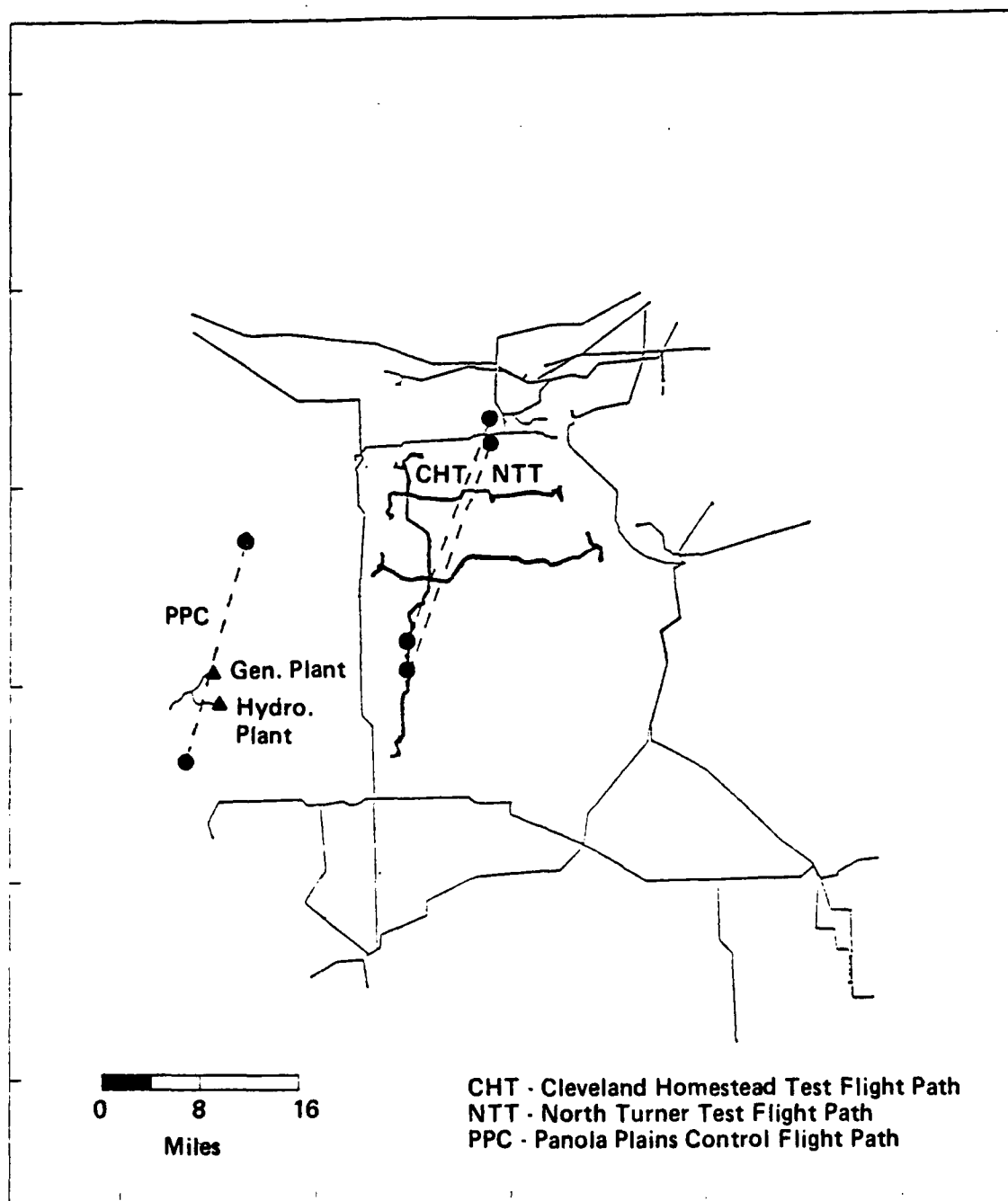


FIGURE A-31. BIRD DISPLACEMENT FLIGHT PATH LOCATIONS RELATIVE TO HIGH VOLTAGE 60 Hz TRANSMISSION LINES.

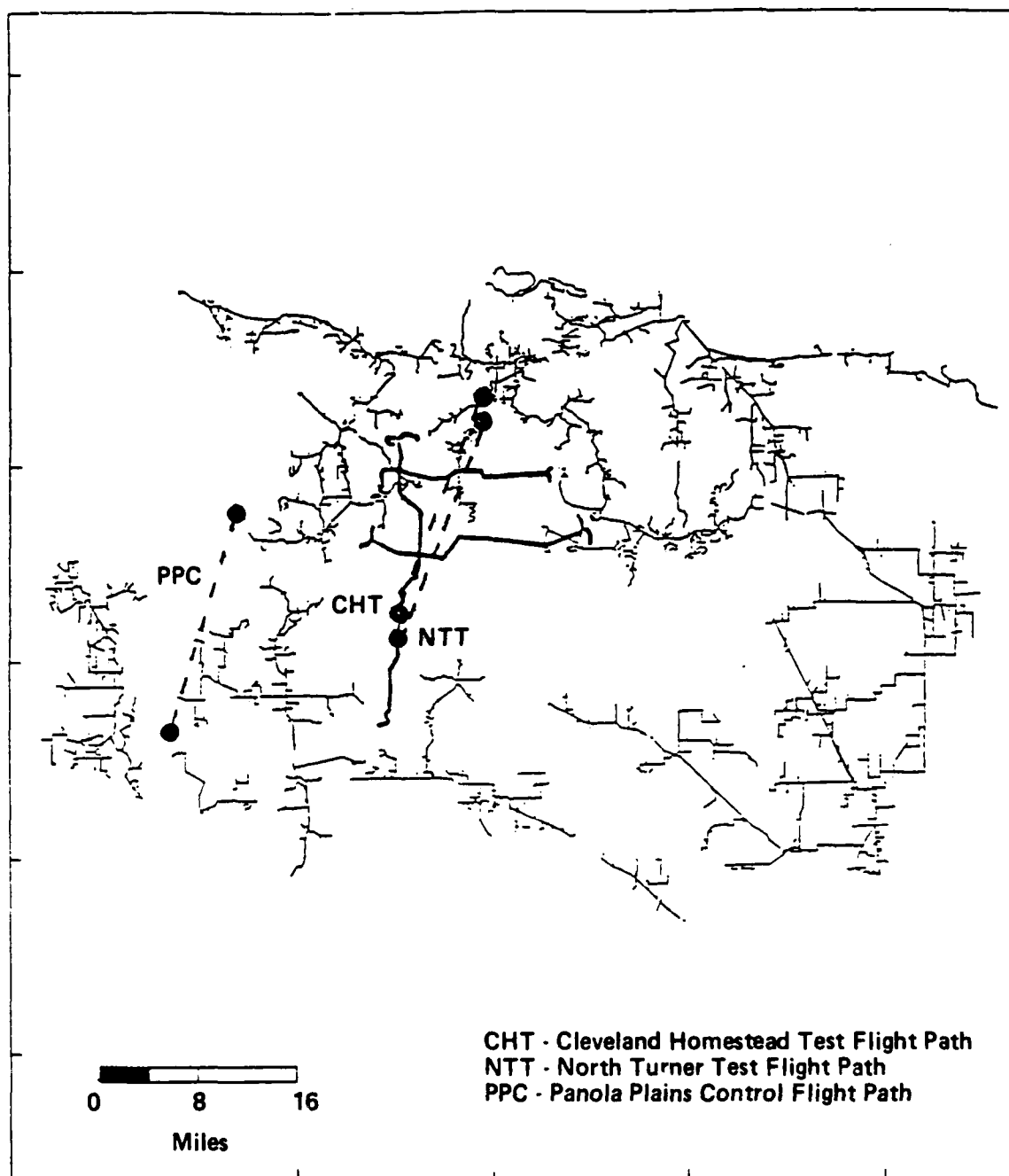


FIGURE A-32. BIRD DISPLACEMENT FLIGHT PATH LOCATIONS RELATIVE TO 60 Hz POWER DISTRIBUTION LINES.

in a location with lower ambient fields prior to testing. IITRI examined two locations (1L2-1 and 1L3-1) proposed by the investigator as candidate sites for the animal holding facility. Both locations are situated in the vicinity of the Panola Plains control site (1C4), i.e., about three miles south of Crystal Falls.

The EM exposures at the candidate sites are presented in Table A-11. Because the MTF was not operating at the time, only 60 Hz EM fields were measured. It is anticipated that the 76 Hz EM exposure at the candidate holding sites will be about the same as experienced at measurement points 1C4-1, -4, and -5.

In the evaluation of the ELF Communications System, 60 Hz fields are considered a contaminant. In this sense, the candidate sites are superior to the present holding facilities at Crystal Falls. The magnetic flux densities at the candidate sites are comparable to those at the control sites (1C1 and 1C4) and are within an order of magnitude of the range of 60 Hz magnetic exposure at the antenna site. The electric fields in the air and earth are considered minor aspects of EM exposure, since caging materials insulate the animals from both fields.

TABLE A-11. EM FIELDS AT CANDIDATE HOLDING FACILITY SITES

Site Number	Transverse E-Field (V/m)	Longitudinal E-Field (mV/m)	Magnetic Flux (mG)
1L2-1	-	0.004	0.002
1L3-1	-	0.036	0.002

- = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.

It is not known if low level, magnetic and electric fields affect vertebrate metabolism, nor which aspects of exposure could be important (i.e., intensity, duration, or both). The assumptions inherent in a protocol of removal of animals from the study sites and their ambient EM environment for testing will still remain for the candidate sites.

APPENDIX B
NATIVE BEES STUDIES

NATIVE BEES STUDIES

On 29 and 30 September and 2 October 1987, IITRI field crews made ELF electromagnetic (EM) field measurements at 14 measurement points at a total of two test and two control sites for the native bees studies. The four study sites were the same as those measured in 1986. One measurement point was added at the Ford 1 site between two bee hutches, the existence of which was unknown to the investigators in the previous year (measurement point 2T1-4). On 11 December 1987, 60 Hz EM field measurements were made at the Ford 1 overwinter test site (2T1-5).

The positions of the four sites relative to the MTF are shown on the composite map in Figure B-1. The site numbers listed on the map are those used by IITRI. Table B-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. Details of measurement locations within sites are given in Figures B-2 through B-5.

TABLE B-1. SITE NO. CROSS-REFERENCE
Native Bees Studies

IITRI Site No.	Investigator's Site Name	Location		
		Township	: Range	: Section(s)
2T1	Ford 1 (F1)	T43N	: R29W	: 14
2T2	Ford 2 (F2)	T43N	: R29W	: 14
2C4	County Line Road (CL)	T43N	: R30W	: 19
2C5	Camp 5 (C5)	T42N	: R31W	: 13

The native bees studies incorporate studies of both nesting and development traits. The electric and magnetic fields present in the air are considered the most important factors in the orientation and site tenacity of bees during their nesting cycle. The electric and magnetic fields in the earth near the surface may be of importance in developmental studies.

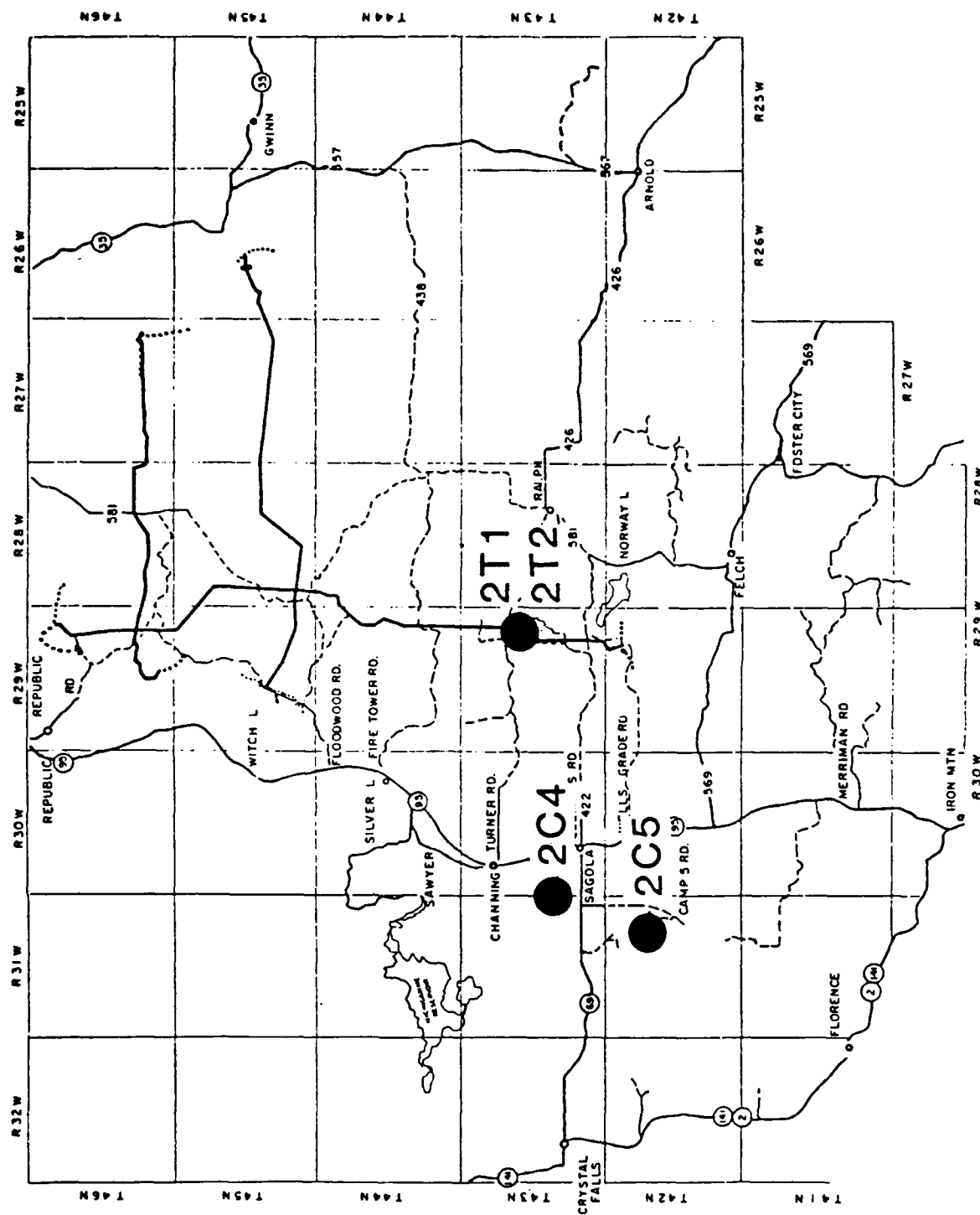
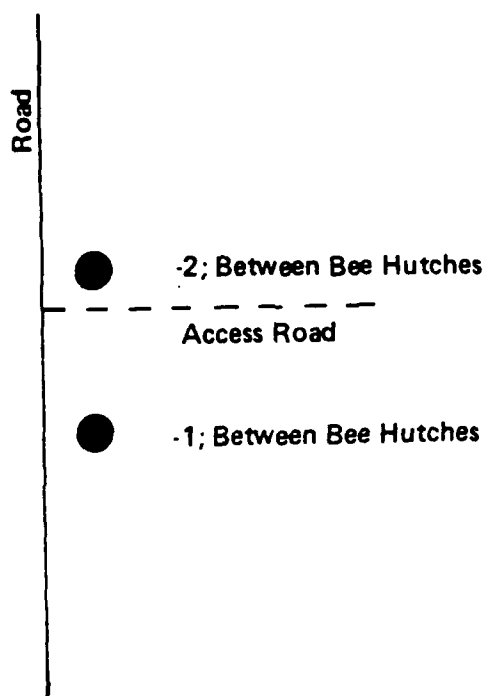
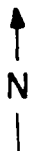


FIGURE B-1. POSITIONS OF NATIVE BEES STUDY SITES RELATIVE TO MICHIGAN TRANSMITTING FACILITY ANTENNA ELEMENTS.



Not to Scale

FIGURE B-2. MEASUREMENT POINTS AT COUNTY LINE ROAD (CL); 2C4 - 1, 2.

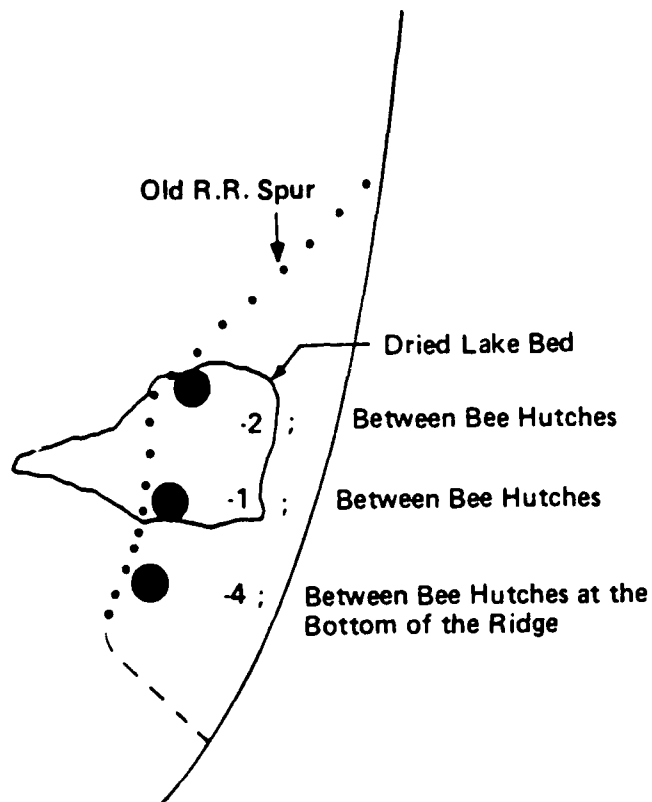


FIGURE B-3. MEASUREMENT POINTS AT CAMP 5 (C5); 2C5 - 1, 2, 4.

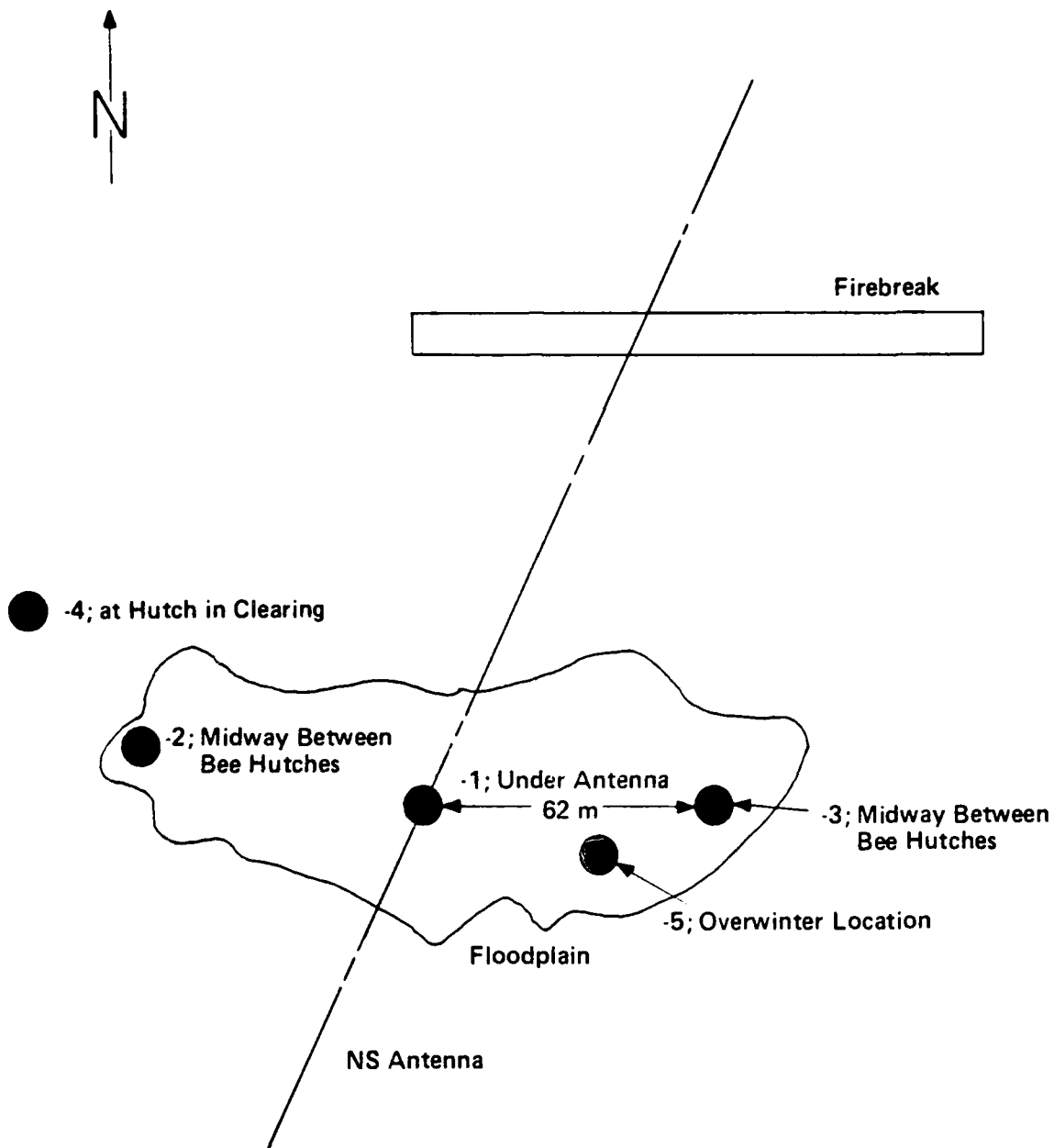


FIGURE B-4. MEASUREMENT POINTS AT FORD 1 (F-1); 2T1, 2, 3, 4, 5.

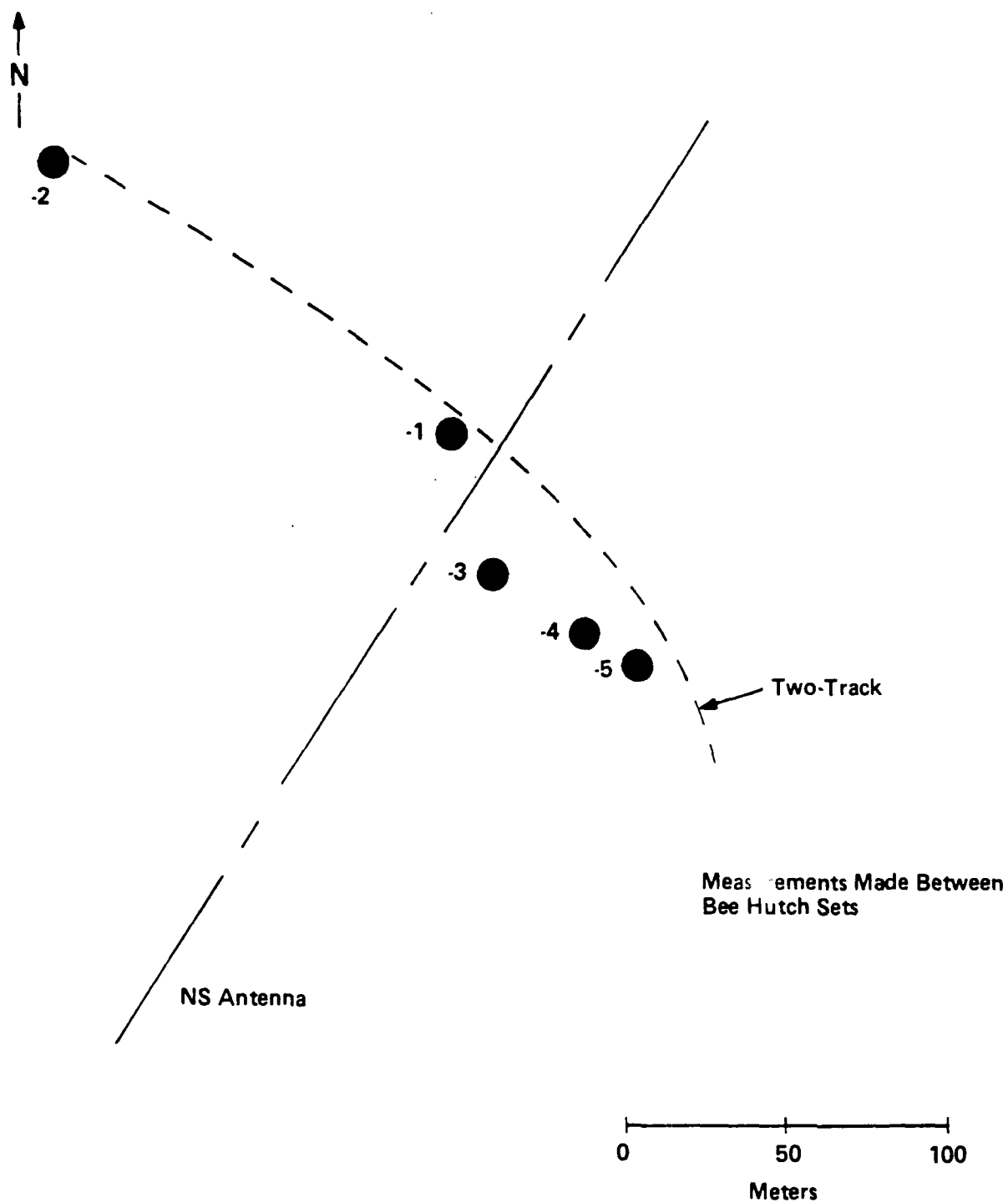


FIGURE B-5. MEASUREMENT POINTS AT FORD 2 (F2); 2T2 - 1 THROUGH 5.

EM field measurements for 1987 and previous years are found in Tables B-2 through B-10. Tables B-2, B-3, and B-4 present 60 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Tables B-5, B-6, and B-7 present 76 Hz data for these three fields at 1986 and 1987 MTF operating currents. Tables B-8, B-9, and B-10 present 76 Hz data extrapolated to a full power condition of 150 amperes.

The 1987 60 Hz measurements at test sites showed the same general trends in field magnitudes as were reported in 1986 as the result of 60 Hz signals from power lines coupled onto the ELF antenna elements. That is, the 60 Hz magnetic flux densities increased and the longitudinal electric fields decreased near the antenna wires in comparison to measurements made prior to antenna construction. However, 1987 60 Hz field levels were about two times greater than those measured in 1986. This is likely the result of several factors. For example, the antenna elements were not grounded at the transmitter during the 60 Hz measurements in 1987 as they were in 1986. This may change the amount of 60 Hz coupling to the antenna elements as is explained in Section 3.5.2.2 of this report. Other changes in the 60 Hz coupling may result from changes in power line loads or changes in earth conductivity as a function of soil moisture.

The EM fields generated by the 60 Hz current on the antenna wire are localized near the antenna and do not affect the 60 Hz fields at the control sites. In fact, all 60 Hz EM field measurements at the control sites for 1987 remained consistent with previous years' measurements.

Since measurements were made at the overwinter site after the final day of MTF operation in 1987, 76 Hz measurements could not be made. Only the 60 Hz longitudinal electric field and magnetic flux measurements were made. The transverse electric field, which was not measured, is not likely to have an effect on the bees, which are enclosed by the nest and shelter materials. The EM fields measured at the overwinter site were in line with those at nearby measurement points.

In 1987, the 76 Hz longitudinal electric field and magnetic flux measured during operation of the east-west antenna element were consistently lower at test sites than those measured in 1986. The same was true of the longitudinal electric field at control sites. The magnetic flux at control sites and the

TABLE B-2. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Native Bees Studies

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c
2C4-1	<0.001	<0.001	-	-	-
2C4-2	-	-	-	-	-
2C5-1	-	<0.001	-	-	-
2C5-2	-	<0.001	-	-	-
2C5-4	-	-	-	-	-
2T1-1	0.004	<0.001	-	-	0.074
2T1-2	-	-	-	-	<0.001
2T1-3	-	-	-	-	<0.001
2T1-4	-	-	-	-	-
2T1-5	-	-	-	-	/
2T2-1	<0.001	<0.001, 0.001	-	-	0.024
2T2-2	-	-	-	-	<0.001
2T2-3	-	-	-	-	0.023
2T2-4	-	-	-	-	0.003
2T2-5	-	-	-	-	0.002

^a = prior to antenna construction.

^b = antenna elements grounded at transmitter (condition 2).

^c = antenna elements connected to transmitter, transmitter off (condition 9).

- = site measurement point not established.

- = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.

TABLE B-3. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Native Bees Studies

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c
2C4-1	0.011	0.102,0.138,0.160	0.104	0.133	0.178
2C4-2	-	-	0.21	0.21	0.26
2C5-1	-	0.64,0.50,0.93	0.69	0.49	0.38
2C5-2	-	0.23	0.40	0.160	0.23
2C5-4	-	-	0.148	0.090	0.098
2T1-1	0.23	0.26	0.22	0.042	0.092
2T1-2	-	-	-	0.051	0.034
2T1-3	-	-	-	0.077	0.051
2T1-4	-	-	-	-	0.040
2T1-5	-	-	-	-	0.050
2T2-1	0.071	0.65,0.88	0.86,0.88	0.23	0.54
2T2-2	-	-	-	0.092	0.100
2T2-3	-	-	-	0.123	0.25
2T2-4	-	-	-	0.078	0.186
2T2-5	-	-	-	0.120	0.23

^a = prior to antenna construction.

^b = antenna elements grounded at transmitter (condition 2).

^c = antenna elements connected to transmitter, transmitter off (condition 9)

- = site measurement point not established.

TABLE B-4. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Native Bees Studies

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c
2C4-1	0.004	0.003,0.004	0.003	0.003	0.006
2C4-2	-	-	0.003	0.003	0.005
2C5-1	-	0.001,0.002	0.002	0.001	0.002
2C5-2	-	<0.001	0.002	0.001	0.002
2C5-4	-	-	0.002	0.002	0.002
2T1-1	0.001	0.002	0.001	0.038	0.042
2T1-2	-	-	-	0.004	0.008
2T1-3	-	-	-	0.005	0.019
2T1-4	-	-	-	-	0.006
2T1-5	-	-	-	-	0.011
2T2-1	0.002	0.001	0.001	0.020	0.058
2T2-2	-	-	-	0.003	0.008
2T2-3	-	-	-	0.015	0.038
2T2-4	-	-	-	0.006	0.018
2T2-5	-	-	-	0.005	0.013

^a = prior to antenna construction.

^b = antenna elements grounded at transmitter (condition 2).

^c = antenna elements grounded at transmitter, transmitter off (condition 9).

- = site measurement point not established.

TABLE B-5. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Native Bees Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M
2C4-1	-	-	-	--	-	-
2C4-2	-	-	-	--	-	-
2C5-1	-	-	-	--	-	-
2C5-2	-	-	-	--	-	-
2C5-4	-	-	-	--	-	-
2T1-1	0.59	-	-	--	2.9	0.003
2T1-2	0.009	-	-	--	0.022	-
2T1-3	0.005	-	-	--	0.019	-
2T1-4	-	-	-	-	0.007	-
2T1-5	-	-	-	-	/	/
2T2-1	0.182	-	-	--	0.48	<0.001
2T2-2	0.005	-	-	--	0.015	<0.001
2T2-3	0.123	-	-	--	0.42	<0.001
2T2-4	0.021	-	-	--	0.061	<0.001
2T2-5	0.012	-	-	--	0.039	<0.001

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

- = site measurement point not established.

- = measurement point expected to be <0.001 V/m based on the longitudinal electric field measurement.

-- = data cannot be extrapolated.

TABLE B-6. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Native Bees Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M
2C4-1	/	/	/	/	0.006	0.003
2C4-2	0.002	0.001	0.001	0.002	0.006	0.004
2C5-1	0.008	0.004	0.006	0.010	0.022	0.018
2C5-2	/	/	/	/	0.008	0.008
2C5-4	/	/	/	/	0.001	0.005
2T1-1	1.97	0.064	0.108	0.180	8.2	0.23
2T1-2	1.08	0.037	0.070	0.117	3.3	0.21
2T1-3	1.31	0.051	0.101	0.168	5.2	0.33
2T1-4	-	-	-	-	4.5	0.191
2T1-5	-	-	-	-	/	/
2T2-1	5.4	0.159	0.086	0.143	32	0.25
2T2-2	1.63	0.054	0.067	0.112	6.0	0.178
2T2-3	3.0	0.087	0.063	0.105	13.5	0.21
2T2-4	1.93	0.053	0.071	0.118	10.4	0.25
2T2-5	3.6	0.101	0.096	0.160	14.0	0.24

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

- = site measurement point not established.

/ = data not taken.

TABLE B-7. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Native Bees Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M
2C4-1	/	/	/	/	0.001	<0.001
2C4-2	<0.001	<0.001	<0.001	--	0.001	<0.001
2C5-1	<0.001	<0.001	<0.001	--	<0.001	<0.001
2C5-2	/	/	/	/	<0.001	<0.001
2C5-4	/	/	/	/	<0.001	<0.001
2T1-1	0.77	0.024	0.004	0.007	3.1	0.004
2T1-2	0.125	0.004	<0.001	--	0.46	0.002
2T1-3	0.131	0.004	0.001	0.002	0.53	0.001
2T1-4	-	-	-	-	0.33	0.002
2T1-5	-	-	-	-	/	/
2T2-1	0.40	0.013	0.002	0.003	1.51	0.004
2T2-2	0.06	0.002	<0.001	--	0.22	0.002
2T2-3	0.35	0.011	0.002	0.003	1.33	0.002
2T2-4	0.158	0.005	0.001	0.002	0.58	0.001
2T2-5	0.124	0.004	0.001	0.002	0.46	0.001

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

- = site measurement point not established.

-- = data cannot be extrapolated.

/ = data not taken.

TABLE B-8. 76 Hz TRANSVERSE ELECTRIC FIELD INTESITIES (V/m)
Native Bees Studies
Data Extrapolated to 150 Ampere Current

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations	
	NS	NEW	SEW	NS	EW
2C4-1	--	--	--	--	--
2C4-2	--	--	--	--	--
2C5-1	--	--	--	--	--
2C5-2	--	--	--	--	--
2C5-4	--	--	--	--	--
2T1-1	22	--	--	29	0.030
2T1-2	0.34	--	--	0.22	--
2T1-3	0.188	--	--	0.190	--
2T1-4	-	-	-	0.070	--
2T1-5	-	-	-	/	/
2T2-1	6.8	--	--	4.8	--
2T2-2	0.188	--	--	0.150	--
2T2-3	4.6	--	--	4.2	--
2T2-4	0.79	--	--	0.61	--
2T2-5	0.45	--	--	0.39	--

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

- = site measurement point not established.

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

TABLE B-9. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Native Bees Studies
Data Extrapolated to 150 Ampere Current

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations	
	NS	NEW	SEW	NS	EW
2C4-1	/	/	/	0.060	0.030
2C4-2	0.075	0.025	0.025	0.060	0.040
2C5-1	0.30	0.100	0.150	0.22	0.180
2C5-2	/	/	/	0.080	0.080
2C5-4	/	/	/	0.010	0.050
2T1-1	74	1.60	2.7	82	2.3
2T1-2	41	0.93	1.75	33	2.1
2T1-3	49	1.28	2.5	52	3.3
2T1-4	-	-	-	45	1.91
2T1-5	-	-	-	/	/
2T2-1	200	4.0	2.2	320	2.5
2T2-2	61	1.35	1.68	60	1.78
2T2-3	113	2.2	1.58	135	2.1
2T2-4	72	1.33	1.78	104	2.5
2T2-5	135	2.5	2.4	140	2.4

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

- = site measurement point not established.

/ = data not taken.

TABLE B-10. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Native Bees Studies
Data Extrapolated to 150 Ampere Current

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations	
	NS	NEW	SEW	NS	EW
2C4-1	/	/	/	0.010	--
2C4-2	--	--	--	0.010	--
2C5-1	--	--	--	--	--
2C5-2	/	/	/	--	--
2C5-4	/	/	/	--	--
2T1-1	29	0.60	0.100	31	0.040
2T1-2	4.7	0.100	--	4.6	0.020
2T1-3	4.9	0.100	0.025	5.3	0.010
2T1-4	-	-	-	3.3	0.020
2T1-5	-	-	-	/	/
2T2-1	15.0	0.33	0.050	15.1	0.040
2T2-2	2.3	0.050	--	2.2	0.020
2T2-3	13.1	0.28	0.050	13.3	0.020
2T2-4	5.9	0.125	0.025	5.8	0.010
2T2-5	4.7	0.100	0.025	4.6	0.010

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

- = site measurement point not established.

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

/ = data not taken.

transverse electric field at test and control sites were below instrument detection levels, so similar comparisons could not be made for these fields.

All 76 Hz fields measured in 1987 during operation of the north-south antenna element were consistent with those from 1986, and dominated the fields measured during operation of the east-west antenna element at the test sites.

Changes in the operational status of the MTF between 1986 and 1987 and their relationship to 76 Hz EM field intensities are discussed in Section 3.5.2.3 of this report.

APPENDIX C
SOIL ARTHROPODS AND EARTHWORMS STUDIES

SOIL ARTHROPODS AND EARTHWORMS STUDIES

On 25 and 28 September 1987, IITRI field crews made ELF electromagnetic (EM) field measurements at a total of eight measurement points at one test and one control site for the soil arthropods and earthworms studies. The study sites and measurement points within the study sites were unchanged from 1986.

The position of the two sites relative to the MTF are shown on the composite map in Figure C-1. The site numbers listed on the map are those used by IITRI. Table C-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. Details of measurement locations within sites are shown in Figures C-2 and C-3.

The soil arthropods and earthworms studies monitor species composition, population age structure, and distribution. The electric and magnetic fields in the earth are considered the most important EM factors influencing soil biota. The electric field in the air is not expected to have a significant impact on the objectives of these studies.

EM field measurements for 1987 and previous years are found in Tables C-2 through C-10. Tables C-2, C-3, and C-4 present 60 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Tables C-5, C-6, and C-7 present 76 Hz data for these fields at 1986 and 1987 MTF operating currents. Tables C-8, C-9, and C-10 present 76 Hz data extrapolated to a full power condition of 150 amperes.

TABLE C-1. SITE NO. CROSS-REFERENCE
Soil Arthropods and Earthworms Studies

IITRI Site No.	Investigator's Site Name	Location		
		Township	: Range	: Section(s)
3T2	South Silver Lake	T44N	: R29W	: 25
3C5	Turner Road	T43N	: R30W	: 11

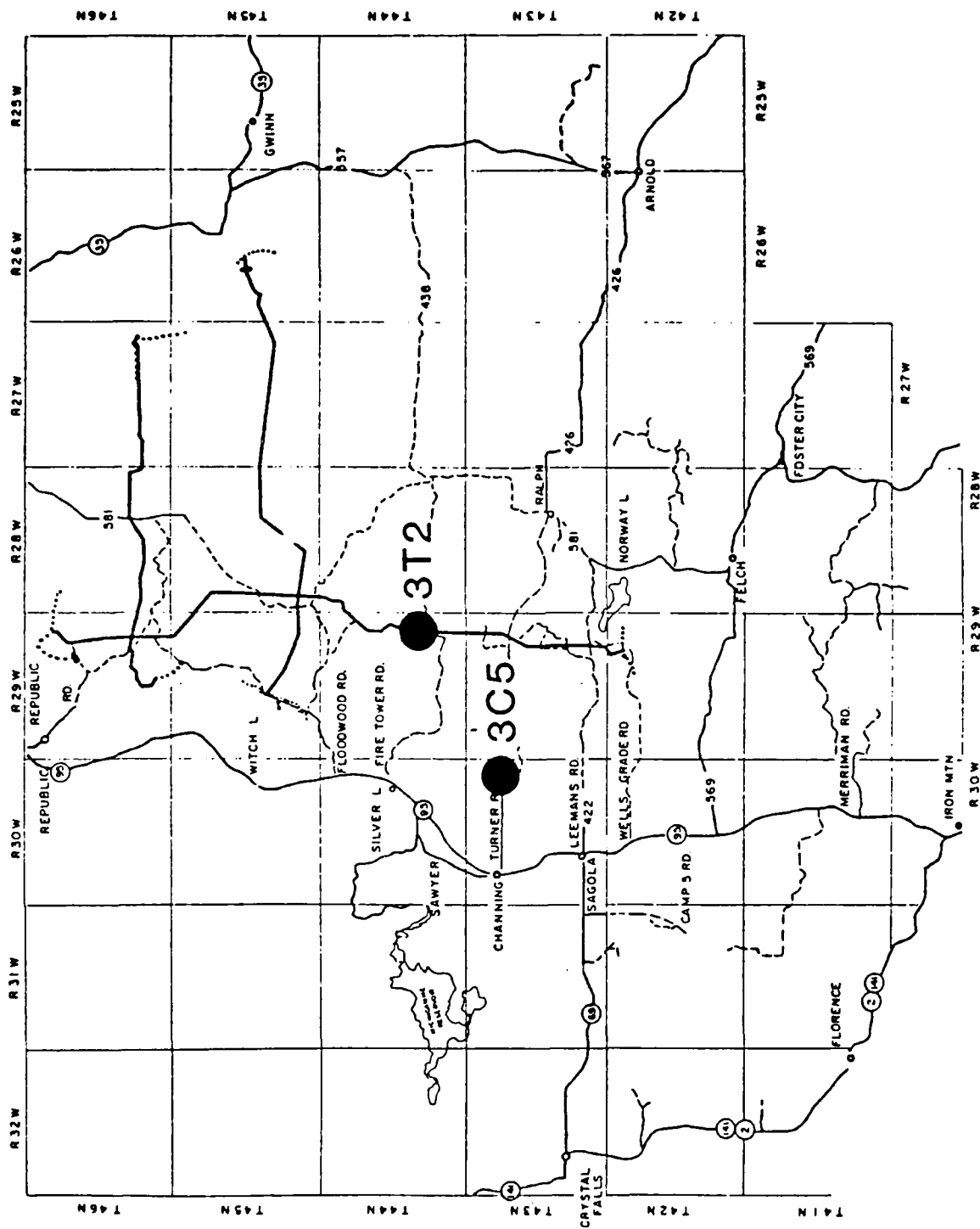
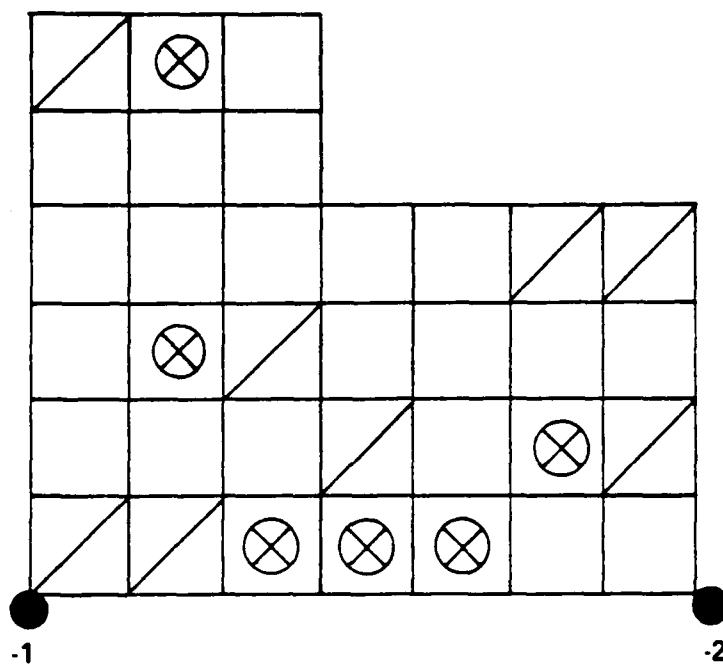


FIGURE C-1. POSITIONS OF SOIL ARTHROPODS AND EARTHWORMS STUDY SITES RELATIVE TO MICHIGAN TRANSMITTING FACILITY ANTENNA ELEMENTS.

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N



Road

FIGURE C-2. MEASUREMENT POINTS AT TURNER ROAD; 3C5 - 1, 2.

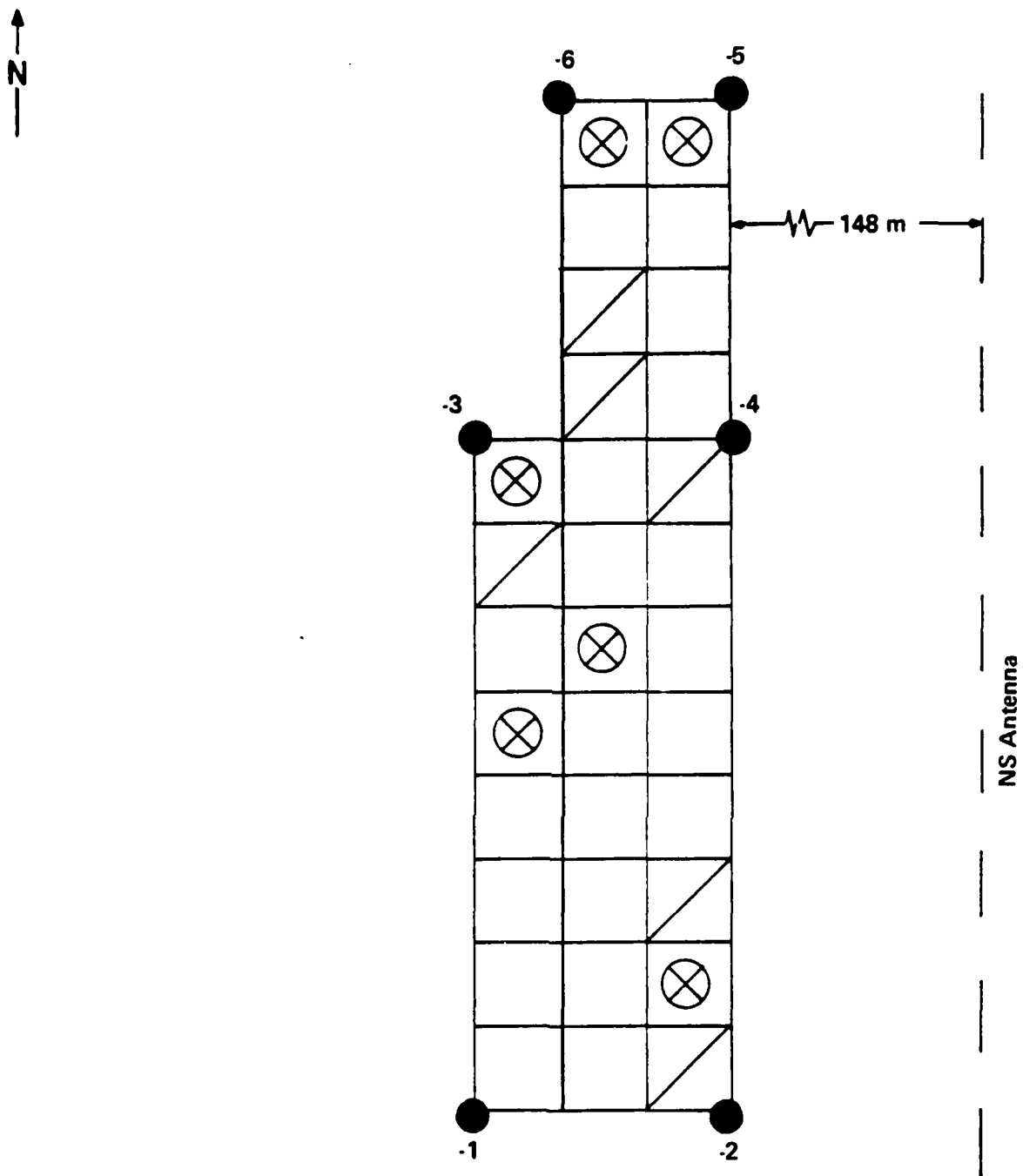


FIGURE C-3. MEASUREMENT POINTS AT SOUTH SILVER LAKE; 3T2 - 1 THROUGH 6.

TABLE C-2. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Soil Arthropods and Earthworms Studies

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c
3C5-1	<0.001	<0.001	-	-	-
3C5-2	-	-	-	-	-
3T2-1	<0.001	<0.001	-	-	-
3T2-2	-	-	-	-	-
3T2-3	-	-	-	-	-
3T2-4	-	-	-	-	-
3T2-5	-	-	-	-	-
3T2-6	-	-	-	-	-

^a = prior to antenna construction.

^b = antenna elements grounded at transmitter (condition 2).

^c = antenna elements connected to transmitter, transmitter off (condition 9).

- = site measurement point not established.

- = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.

TABLE C-3. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Soil Arthropods and Earthworms Studies

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c
3C5-1	0.063	0.018,0.032	0.036	0.027	0.054
3C5-2	-	-	-	0.027	0.071
3T2-1	0.106	0.129,0.27	0.194	0.045	0.042
3T2-2	-	-	-	0.068	0.049
3T2-3	-	-	-	0.038	0.043
3T2-4	-	-	-	0.045	0.039
3T2-5	-	-	-	0.044	0.045
3T2-6	-	-	-	0.048	0.033

^a = prior to antenna construction.

^b = antenna elements grounded at transmitter (condition 2).

^c = antenna elements connected to transmitter, transmitter off (condition 9).

- = site measurement point not established.

**TABLE C-4. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Arthropods and Earthworms Studies**

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c
3C5-1	0.001	0.001	0.001	0.001	0.002
3C5-2	-	-	-	<0.001	0.001
3T2-1	<0.001	<0.001	0.001	0.005	0.002
3T2-2	-	-	-	0.006	0.003
3T2-3	-	-	-	0.004	0.003
3T2-4	-	-	-	0.005	0.003
3T2-5	-	-	-	0.005	0.003
3T2-6	-	-	-	0.004	0.003

^a = prior to antenna construction.

^b = antenna elements grounded at transmitter (condition 2).

^c = antenna elements connected to transmitter, transmitter off (condition 9).

- = site measurement point not established.

**TABLE C-5. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Soil Arthropods and Earthworms Studies
Measured (M) and Extrapolated (Ex) Data**

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M
3C5-1	-	-	-	--	-	-
3C5-2	-	-	-	--	-	-
3T2-1	0.002	-	-	--	0.006	-
3T2-2	0.002	-	-	--	-	-
3T2-3	0.002	-	-	--	0.006	-
3T2-4	0.002	-	-	--	0.006	-
3T2-5	0.002	-	-	--	0.006	-
3T2-6	0.002	-	-	--	0.006	-

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

- = measurement expected to be <0.001 based on the longitudinal electric field measurement.

-- = data cannot be extrapolated.

TABLE C-6. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Soil Arthropods and Earthworms Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M
3C5-1	0.005	0.001	0.002	0.003	0.020	0.006
3C5-2	0.009	0.001	0.003	0.005	0.034	0.009
3T2-1	1.33	0.057	0.188	0.31	5.4	0.54
3T2-2	1.46	0.064	0.24	0.40	6.3	0.71
3T2-3	1.19	0.047	0.149	0.25	5.3	0.60
3T2-4	1.47	0.060	0.20	0.33	5.6	0.47
3T2-5	1.56	0.070	0.23	0.38	5.7	0.61
3T2-6	1.20	0.056	0.180	0.30	5.5	0.54

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

TABLE C-7. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Arthropods and Earthworms Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M
3C5-1	<0.001	<0.001	<0.001	--	0.002	0.001
3C5-2	<0.001	<0.001	<0.001	--	0.002	0.001
3T2-1	0.048	0.001	0.001	0.002	0.187	0.003
3T2-2	0.060	0.002	0.001	0.002	0.23	0.003
3T2-3	0.046	0.001	0.001	0.002	0.182	0.002
3T2-4	0.055	0.002	0.001	0.002	0.23	0.003
3T2-5	0.057	0.002	0.001	0.002	0.22	0.003
3T2-6	0.049	0.001	0.001	0.002	0.190	0.003

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

-- = data cannot be extrapolated.

TABLE C-8. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Soil Arthropods and Earthworms Studies
Data Extrapolated to 150 Ampere Current

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations	
	NS	NEW	SEW	NS	EW
3C5-1	--	--	--	--	--
3C5-2	--	--	--	--	--
3T2-1	0.075	--	--	0.060	--
3T2-2	0.075	--	--	--	--
3T2-3	0.075	--	--	0.060	--
3T2-4	0.075	--	--	0.060	--
3T2-5	0.075	--	--	0.060	--
3T2-6	0.075	--	--	0.060	--

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

TABLE C-9. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Soil Arthropods and Earthworms Studies
Data Extrapolated to 150 Ampere Current

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations	
	NS	NEW	SEW	NS	EW
3C5-1	0.188	0.025	0.050	0.20	0.060
3C5-2	0.34	0.025	0.075	0.34	0.090
3T2-1	50	1.43	4.7	54	5.4
3T2-2	55	1.60	6.0	63	7.1
3T2-3	45	1.18	3.7	53	6.0
3T2-4	55	1.50	5.0	56	4.7
3T2-5	59	1.75	5.8	57	6.1
3T2-6	45	1.40	4.5	55	5.4

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

TABLE C-10. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Arthropods and Earthworms Studies
Data Extrapolated to 150 Ampere Current

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations	
	NS	NEW	SEW	NS	EW
3C5-1	--	--	--	0.020	0.010
3C5-2	--	--	--	0.020	0.010
3T2-1	1.80	0.025	0.025	1.87	0.030
3T2-2	2.3	0.050	0.025	2.3	0.030
3T2-3	1.73	0.025	0.025	1.82	0.020
3T2-4	2.1	0.050	0.025	2.3	0.030
3T2-5	2.1	0.050	0.025	2.2	0.030
3T2-6	1.84	0.025	0.025	1.90	0.030

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

The 1987 60 Hz measurements at test sites showed the same general trends in field magnitudes as were reported in 1986 as the result of 60 Hz signals from power lines coupled onto the ELF antenna elements. That is, the 60 Hz magnetic flux densities increased and the longitudinal electric fields decreased near the antenna wires in comparison to measurements made prior to antenna construction. However, 1987 60 Hz magnetic field levels were about two times lower than those measured in 1986. This is likely the result of several factors. For example, the antenna elements were not grounded at the transmitters during the 60 Hz measurements in 1987 as they were in 1986. This may change the amount of 60 Hz coupling to the antenna elements, as is explained in Section 3.5.2.2 of this report. Other changes in the 60 Hz coupling may result from changes in power line loads or changes in earth conductivity as a function of soil moisture.

The EM fields generated by the 60 Hz current on the antenna wire are localized near the antenna and do not affect the 60 Hz fields at the control site. However, all 60 Hz EM field measurements at the control site can be directly influenced by changes in power line loads and by changes in earth conductivity. This likely accounts for a two- to threefold increase in the 60 Hz longitudinal electric fields at the control site in 1987.

In 1987, the 76 Hz longitudinal electric field and magnetic flux measured during operation of the east-west antenna element were typically lower at test sites than those measured in 1986. The same was true of the longitudinal electric field at control sites. The magnetic flux at control sites and the transverse electric field at test and control sites were below instrument detection levels, so similar comparisons could not be made for these fields.

All 76 Hz fields measured in 1987 during operation of the north-south antenna element were consistent with those from 1986, and dominated the fields measured during operation of the east-west antenna element at the test sites.

Changes in the operational status of the MTF between 1986 and 1987 and their relationship to 76 Hz EM field intensities are discussed in Section 3.5.2.3 of this report.

APPENDIX D
UPLAND FLORA AND SOIL MICROFLORA STUDIES

UPLAND FLORA AND SOIL MICROFLORA STUDIES

On 22 and 23 September and 5 and 7 October 1987, IITRI field crews made ELF electromagnetic (EM) field measurements at 32 measurement points at a total of two test sites, one control site, and three sample collection points. The test and control sites are the same as those measured in 1986. Three new measurement points were established in 1987 at the three sample collection points for red maple leaves, oak leaves, and pine needles (4S1, 4S2, and 4S3, respectively). The sample collection sites are used to collect foliage to be distributed at the three study sites for decomposition experiments.

The positions of the study sites relative to the MTF are shown on the composite map in Figure D-1. The site numbers listed on the map are those used by IITRI. Table D-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. Details of measurement locations within sites are shown in Figures D-2 through D-6.

TABLE D-1. SITE NO. CROSS-REFERENCE
Upland Flora and Soil Microflora Studies

IITRI Site No.	Investigator's Site Name	Location		
		Township	: Range	: Section(s)
4T2	Martell's Lake (Overhead): ML	T45N	: R29W	: 28
4T4	Martell's Lake (Buried): EP	T45N	: R29W	: 28
4C1	Paint Pond Road Control	T41N	: R32W	: 3
4S1	Red Maple Leaf Collection	T55N	: R35W	: 21
4S2	Oak Leaf Collection	T41N	: R32W	: 3
4S3	Pine Needle Collection	T54N	: R34W	: 5

The test sites straddle the antenna and grounding elements of the MTF. The control site is located more than 28 miles from the nearest antenna element, and is arranged in a manner similar to the test sites. The antenna test site and the control site each consist of three overstory tree plots (pole stands), three plots cleared and planted with red pine seedlings (plantations), and three plots set aside for the study of herbaceous plants

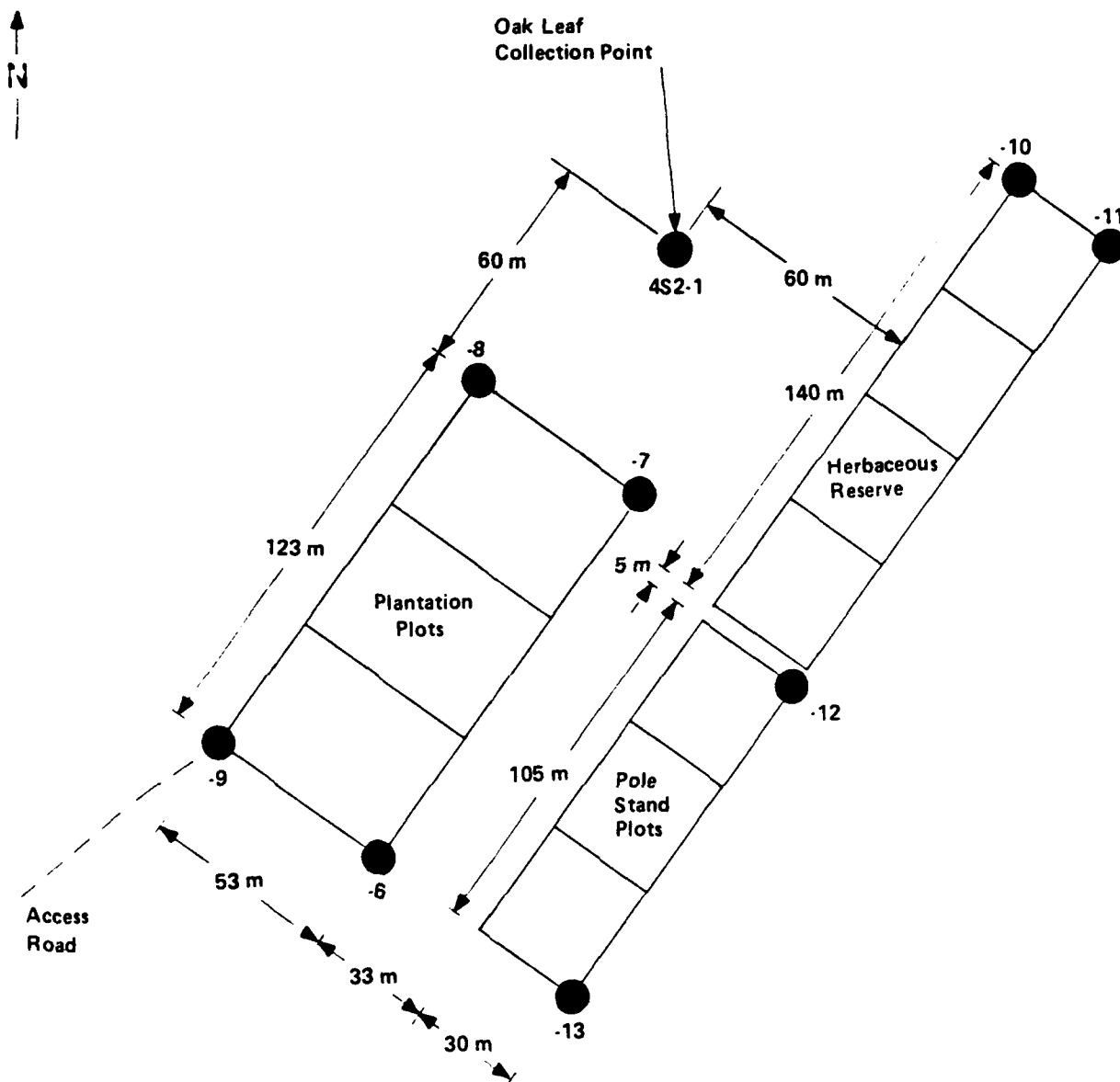


FIGURE D-2. MEASUREMENT POINTS AT PAINT POND ROAD CONTROL; 4C1-6 THROUGH 13, AND OAK LEAF COLLECTION SITE; 4S2-1.

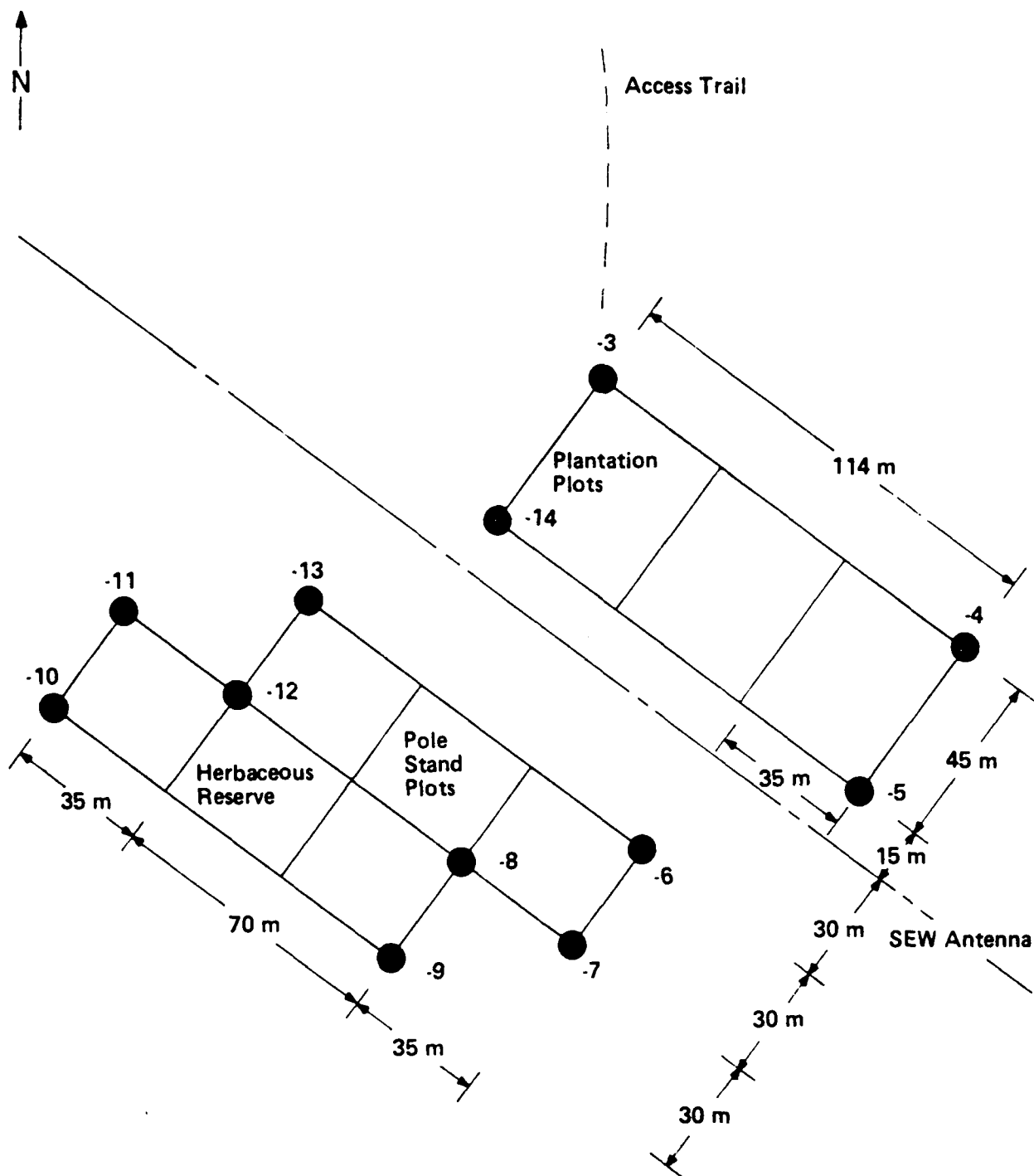


FIGURE D-3. MARTELL'S LAKE (OVERHEAD): ML;4T2 - 3 THROUGH 14.

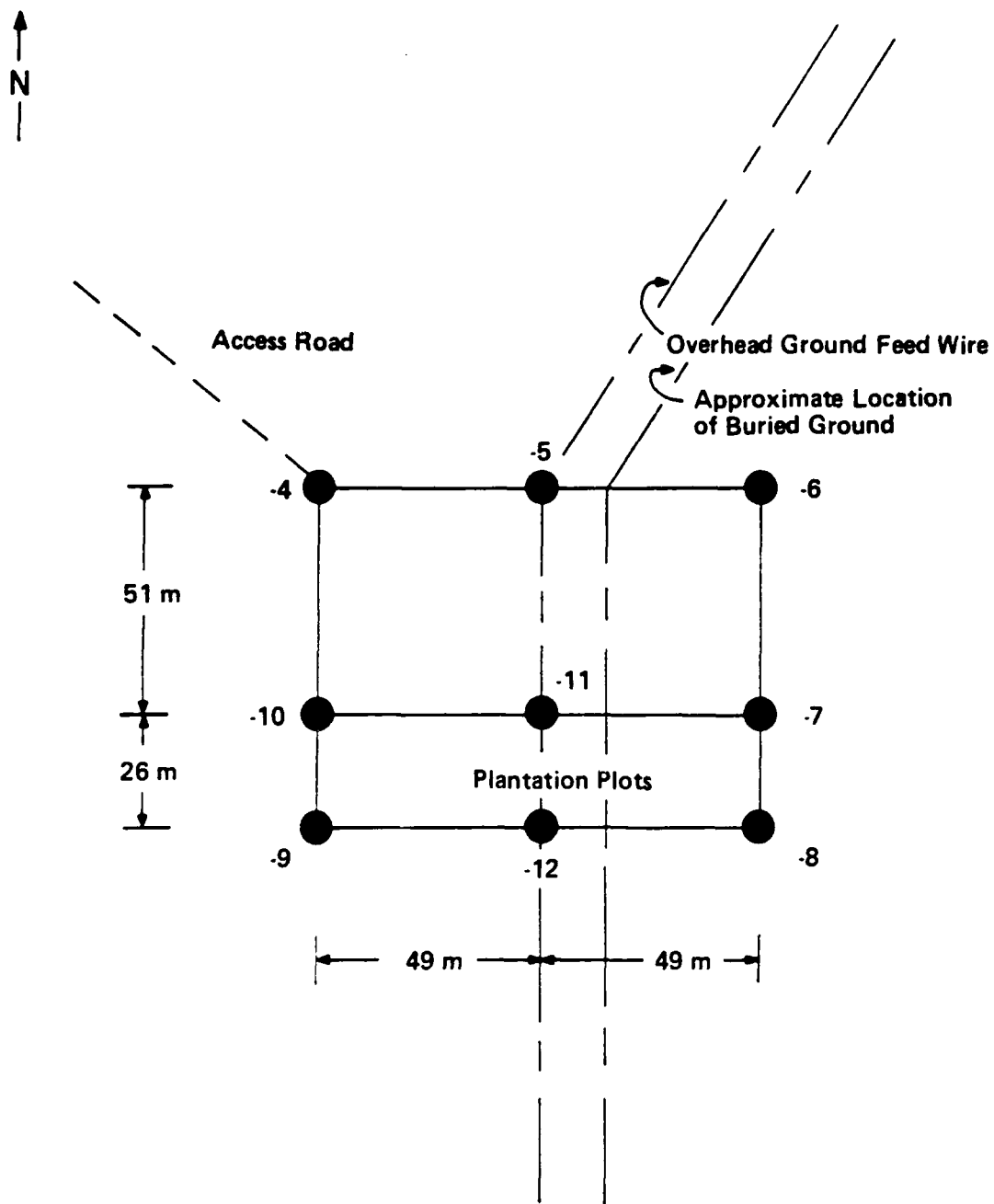


FIGURE D-4. MARTELL'S LAKE (BURIED): EP; 4T4 - 4 THROUGH 12.

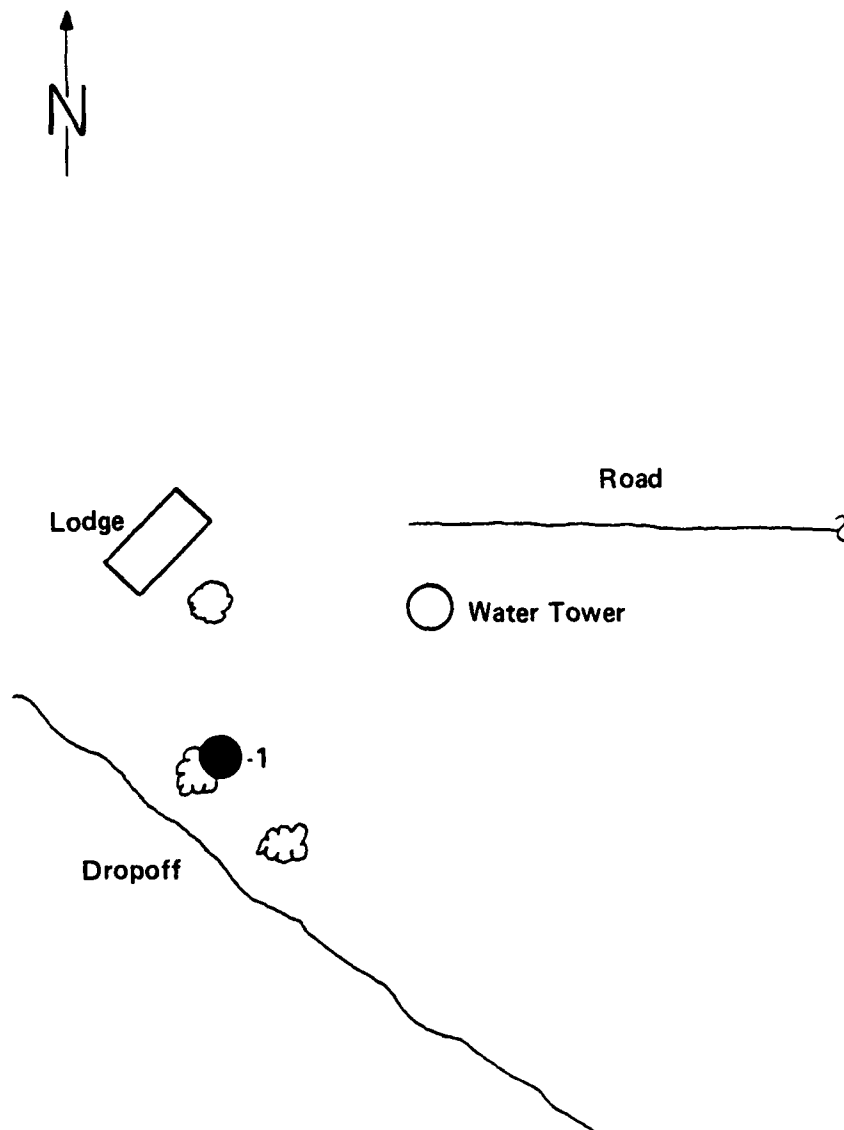


FIGURE D-5. MEASUREMENT POINT AT RED MAPLE LEAF SAMPLE COLLECTION SITE; 4S1.

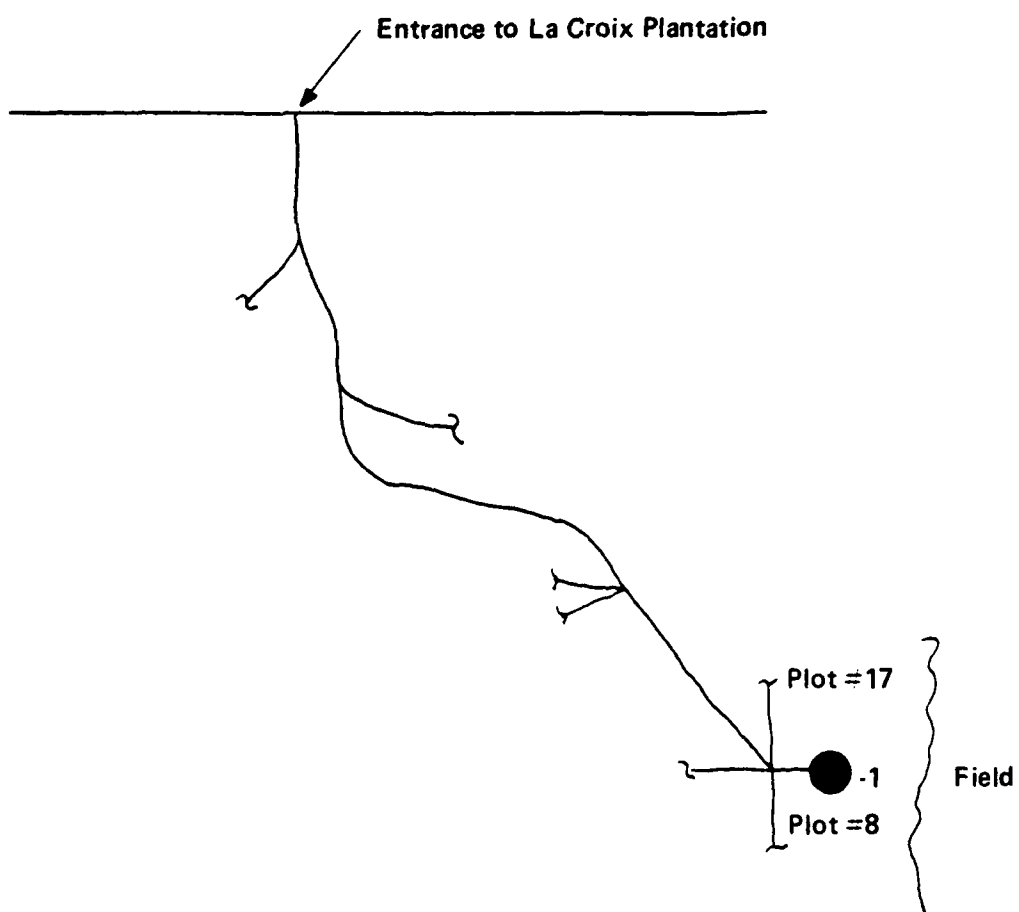


FIGURE D-6. MEASUREMENT POINT AT THE PINE NEEDLE SAMPLE COLLECTION SITE; 4S3.

(reserves). The grounding test site consists of only three plots cleared and planted with red pine. No overstory tree plots or herbaceous reserve were established at the grounding test site because the required buffer strips would have resulted in the biota being at too great a distance from the grounding elements for meaningful EM exposure.

The major themes of the upland flora and microflora studies are the functional and structural aspects of organic material cycling. These studies will investigate and characterize trees, herbaceous plants, and microflora (fungi and streptomycetes) populations. The electric and magnetic fields in the earth are considered important EM factors influencing soil biota and processes. The electric and magnetic fields in the air might influence any object extending above the surface of the earth. Since the electric field in the air can be effectively shunted by trees or plants on the perimeter of a given study plot, special care was taken in characterizing the ambient electric field intensities across the plot.

EM field measurements for 1987 and previous years are found in Tables D-2 through D-10. Tables D-2, D-3, and D-4 present 60 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Tables D-5, D-6, and D-7 present 76 Hz data for these three fields at 1986 and 1987 MTF operating currents. Tables D-8, D-9, and D-10 present 76 Hz data extrapolated to a full power condition of 150 amperes.

The 1987 60 Hz measurements at the overhead antenna test site showed the same general trends in field magnitudes as were reported in 1986 as the result of 60 Hz signals from power lines coupled onto the ELF antenna elements. That is, the 60 Hz magnetic flux densities increased and the longitudinal electric fields decreased near the antenna wires in comparison to measurements made prior to antenna construction. However, the 1987 60 Hz magnetic flux densities at the overhead antenna site and both the longitudinal electric fields and magnetic flux densities at the ground test site increased significantly from 1986 levels for measurement points nearest the antenna and ground wires. This is likely the result of several factors. For example, the antenna elements were not grounded at the transmitters during the 60 Hz measurement in 1987 as they were in 1986. This may change the amount of 60 Hz coupling to the antenna elements, as is explained in Section 3.5.2.2 of this

**TABLE D-2. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Upland Flora and Soil Microflora Studies**

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c
4C1-6	-	0.003	-	-	-
4C1-7	-	0.006	-	-	-
4C1-8	-	0.004	-	-	-
4C1-9	-	0.002	-	-	-
4C1-10	-	-	-	-	-
4C1-11	-	-	-	-	-
4C1-12	-	-	-	-	-
4C1-13	-	-	-	-	-
4T2-3	-	0.001	-	-	-
4T2-4	-	-	-	-	-
4T2-5	-	-	-	-	-
4T2-6	-	-	-	-	-
4T2-7	-	-	-	-	-
4T2-8	-	-	-	-	-
4T2-9	-	-	-	-	-
4T2-10	-	-	-	-	-
4T2-11	-	-	-	-	-
4T2-12	-	-	-	-	-
4T2-13	-	-	-	-	-
4T2-14	-	-	-	-	-
4T4-4	-	0.003	-	-	<0.001
4T4-5	-	-	-	-	0.006
4T4-6	-	-	-	-	-
4T4-7	-	-	-	-	-
4T4-8	-	-	-	-	-
4T4-9	-	-	-	-	-
4T4-10	-	-	-	-	-
4T4-11	-	-	-	-	0.010
4T4-12	-	-	-	-	0.005
4S1-1	-	-	-	-	0.013
4S2-1	-	-	-	-	-
4S3-1	-	-	-	-	<0.001

^a = prior to antenna construction.

^b = antenna elements grounded at transmitter (condition 2).

^c = antenna elements connected to transmitter, transmitter off (condition 9).

- = site measurement point not established.

- = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.

TABLE D-3. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Studies

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c
4C1-6	-	0.022	0.016	0.005	0.043
4C1-7	-	0.143	0.123	0.077	0.178
4C1-8	-	0.104	0.117	0.077	0.131
4C1-9	-	0.011	0.019	0.024	0.034
4C1-10	-	-	0.090	0.068	0.118
4C1-11	-	-	0.160	0.107	0.132
4C1-12	-	-	0.104	0.101	0.075
4C1-13	-	-	0.040	0.030	0.046
4T2-3	-	0.51	0.39	0.194	0.27
4T2-4	-	-	0.27	0.24	0.30
4T2-5	-	-	0.43	0.32	0.20
4T2-6	-	-	0.66	0.46	0.192
4T2-7	-	-	0.42	0.52	0.197
4T2-8	-	-	0.47	0.190	0.22
4T2-9	-	-	0.49	0.31	0.183
4T2-10	-	-	0.44	0.32	0.155
4T2-11	-	-	0.51	0.40	0.31
4T2-12	-	-	0.47	0.38	0.24
4T2-13	-	-	0.76	0.31	0.31
4T2-14	-	-	0.61	0.29	0.35
4T4-4	-	0.72	0.42	0.185	0.56
4T4-5	-	-	0.58	0.58	4.3
4T4-6	-	-	0.22	0.16	0.61
4T4-7	-	-	0.44	0.29	0.64
4T4-8	-	-	0.42	0.193	0.40
4T4-9	-	-	0.50	0.21	0.27
4T4-10	-	-	0.42	0.22	0.29
4T4-11	-	-	0.40	0.60	2.7
4T4-12	-	-	-	0.75	3.4
4S1-1	-	-	-	-	8.5
4S2-1	-	-	-	-	0.155
4S3-1	-	-	-	-	0.65

^a = prior to antenna construction.

^b = antenna elements grounded at transmitter (condition 2).

^c = antenna elements connected to transmitter, transmitter off (condition 9).

- = site measurement point not established.

TABLE D-4. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Upland Flora and Soil Microflora Studies

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c
4C1-6	-	0.003	0.003	0.003	0.002
4C1-7	-	0.003	0.002	0.001	0.003
4C1-8	-	0.003	0.003	0.002	0.003
4C1-9	-	0.003	0.003	0.002	0.001
4C1-10	-	-	0.002	0.002	0.002
4C1-11	-	-	0.002	0.002	0.002
4C1-12	-	-	0.002	0.003	0.001
4C1-13	-	-	0.002	0.003	0.001
4T2-3	-	0.002	0.001	0.001	0.003
4T2-4	-	-	0.001	0.001	0.003
4T2-5	-	-	0.001	0.007	0.017
4T2-6	-	-	0.001	0.006	0.006
4T2-7	-	-	0.001	0.004	0.004
4T2-8	-	-	0.001	0.002	0.004
4T2-9	-	-	0.001	0.003	0.003
4T2-10	-	-	0.001	0.003	0.003
4T2-11	-	-	0.001	0.004	0.005
4T2-12	-	-	0.002	0.004	0.005
4T2-13	-	-	0.001	0.005	0.008
4T2-14	-	-	0.002	0.011	0.018
4T4-4	-	0.004	0.002	0.001	0.003
4T4-5	-	-	0.002	0.006	0.010
4T4-6	-	-	0.002	0.001	0.004
4T4-7	-	-	0.001	0.001	0.004
4T4-8	-	-	0.002	0.001	0.004
4T4-9	-	-	0.002	0.001	0.002
4T4-10	-	-	0.001	0.001	0.002
4T4-11	-	-	0.002	0.002	0.012
4T4-12	-	-	-	0.002	0.010
4S1-1	-	-	-	-	0.035
4S2-1	-	-	-	-	0.003
4S3-1	-	-	-	-	0.036

^a = prior to antenna construction.

^b = antenna elements grounded at transmitter (condition 2).

^c = antenna elements connected to transmitter, transmitter off (condition 9).

- = site measurement point not established.

TABLE D-5. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Upland Flora and Soil Microflora Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M
4C1-6	-	-	-	-	-	-
4C1-7	-	-	-	-	-	-
4C1-8	-	-	-	-	-	-
4C1-9	-	-	-	-	-	-
4C1-10	-	-	-	-	-	-
4C1-11	-	-	-	-	-	-
4C1-12	-	-	-	-	-	-
4C1-13	-	-	-	-	-	-
4T2-3	-	-	0.004	0.007	0.002	0.014
4T2-4	-	-	0.005	0.008	0.001	0.014
4T2-5	0.018	-	0.092	0.153	0.003	0.23
4T2-6	-	-	0.005	0.008	0.003	0.013
4T2-7	-	-	0.007	0.012	0.001	0.018
4T2-8	-	-	0.004	0.007	0.002	0.012
4T2-9	-	-	0.005	0.008	0.002	0.010
4T2-10	-	-	0.004	0.007	0.002	0.011
4T2-11	-	-	0.003	0.005	0.002	0.012
4T2-12	-	-	0.002	0.003	0.002	0.014
4T2-13	-	-	0.005	0.008	0.002	0.012
4T2-14	0.030	-	0.155	0.26	0.003	0.186
4T4-4	-	-	0.006	0.010	0.002	0.005
4T4-5	0.033	0.008	0.20	0.33	0.019	0.27
4T4-6	0.005	-	0.023	0.038	0.002	0.021
4T4-7	-	-	0.006	0.010	0.002	0.015
4T4-8	-	-	0.008	0.013	0.002	0.016
4T4-9	-	-	0.009	0.015	0.001	0.008
4T4-10	-	-	0.007	0.012	0.001	0.001
4T4-11	-	0.005	0.38	0.63	0.025	0.43
4T4-12	0.055	0.005	0.43	0.72	0.017	0.30
4S1-1	-	-	-	-	-	-
4S2-1	-	-	-	-	-	-
4S3-1	-	-	-	-	-	-

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

- = site measurement point not established.

- = measurement expected to be <0.001 based on the longitudinal electric field measurement.

TABLE D-6. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M
4C1-6	-	-	-	--	0.002	0.002
4C1-7	-	-	-	--	0.005	0.006
4C1-8	-	-	-	--	0.004	0.004
4C1-9	<0.001	<0.001	<0.001	--	0.002	0.002
4C1-10	-	-	-	--	0.005	0.004
4C1-11	-	-	-	--	0.006	0.005
4C1-12	-	-	-	--	0.004	0.003
4C1-13	-	-	-	--	0.002	0.002
4T2-3	1.31	0.22	6.3	10.5	1.36	15.2
4T2-4	1.05	0.22	5.0	8.3	1.70	10.7
4T2-5	1.18	0.24	5.3	8.8	1.46	12.7
4T2-6	1.11	0.27	4.4	7.3	2.2	12.4
4T2-7	1.13	0.23	5.3	8.8	1.31	9.7
4T2-8	1.32	0.25	5.7	9.5	1.81	15.8
4T2-9	1.17	0.21	5.1	8.5	1.46	13.7
4T2-10	0.97	0.22	4.1	6.8	1.84	10.5
4T2-11	1.14	0.21	5.0	8.3	2.2	10.7
4T2-12	1.06	0.21	4.3	7.2	1.93	13.5
4T2-13	1.12	0.64	5.4	9.0	1.74	14.9
4T2-14	1.07	0.175	5.1	8.5	1.66	14.3
4T4-4	0.33	0.181	1.46	2.4	1.63	3.7
4T4-5	13.8	2.0	81	135	14.0	194
4T4-6	1.22	0.22	6.2	10.3	2.2	12.9
4T4-7	0.94	0.175	5.5	9.2	2.0	14.1
4T4-8	0.91	0.188	5.3	8.8	1.36	10.7
4T4-9	0.29	0.130	1.32	2.2	1.08	3.0
4T4-10	0.29	0.169	1.63	2.7	1.35	3.9
4T4-11	0.59	1.82	89	148	10.7	178
4T4-12	21	2.2	118	197	13.8	260
4S1-1	-	-	-	-	<0.001	<0.001
4S2-1	-	-	-	-	0.005	0.005
4S3-1	-	-	-	-	<0.001	<0.001

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

- = site measurement point not established.

- = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.

-- = data cannot be extrapolated.

/ = data not taken.

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TABLE D-7. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Upland Flora and Soil Microflora Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M
4C1-6	-	-	-	--	<0.001	<0.001
4C1-7	-	-	-	--	<0.001	<0.001
4C1-8	-	-	-	--	<0.001	<0.001
4C1-9	<0.001	<0.001	<0.001	--	<0.001	<0.001
4C1-10	-	-	-	--	<0.001	<0.001
4C1-11	-	-	-	--	<0.001	<0.001
4C1-12	-	-	-	--	<0.001	<0.001
4C1-13	-	-	-	--	<0.001	<0.001
4T2-3	0.047	0.001	0.22	0.37	0.008	0.55
4T2-4	0.049	0.001	0.24	0.40	0.008	0.57
4T2-5	0.197	<0.001	1.00	1.67	0.011	2.4
4T2-6	0.058	0.001	0.44	0.73	0.006	1.16
4T2-7	0.046	0.001	0.22	0.37	0.006	0.59
4T2-8	0.045	0.001	0.22	0.37	0.006	0.59
4T2-9	0.029	0.001	0.138	0.23	0.007	0.38
4T2-10	0.033	0.001	0.149	0.25	0.006	0.39
4T2-11	0.043	0.001	0.21	0.35	0.006	0.56
4T2-12	0.047	0.001	0.23	0.38	0.006	0.61
4T2-13	0.086	<0.001	0.43	0.72	0.005	1.14
4T2-14	0.21	<0.001	1.03	1.72	0.012	2.5
4T4-4	0.019	<0.001	0.096	0.160	0.005	0.24
4T4-5	0.114	0.001	0.57	0.95	0.008	1.40
4T4-6	0.045	0.001	0.22	0.37	0.008	0.53
4T4-7	0.038	0.001	0.186	0.31	0.008	0.45
4T4-8	0.035	0.001	0.179	0.30	0.007	0.43
4T4-9	0.025	0.21	0.118	0.197	0.005	0.29
4T4-10	0.022	<0.001	0.116	0.193	0.005	0.27
4T4-11	0.161	0.001	0.80	1.33	0.011	1.89
4T4-12	0.115	0.001	0.58	0.97	0.010	1.37
4S1-1	-	-	-	-	<0.001	<0.001
4S2-1	-	-	-	-	<0.001	<0.001
4S3-1	-	-	-	-	<0.001	<0.001

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

- = site measurement point not established.

- = measurement expected to be <0.001 based on the longitudinal electric field measurement.

-- = data cannot be extrapolated.

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TABLE D-8. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Upland Flora and Soil Microflora Studies
Data Extrapolated to 150 Ampere Current

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations	
	NS	NEW	SEW	NS	EW
4C1-6	--	--	--	--	--
4C1-7	--	--	--	--	--
4C1-8	--	--	--	--	--
4C1-9	--	--	--	--	--
4C1-10	--	--	--	--	--
4C1-11	--	--	--	--	--
4C1-12	--	--	--	--	--
4C1-13	--	--	--	--	--
4T2-3	--	--	0.100	0.020	0.140
4T2-4	--	--	0.125	0.010	0.140
4T2-5	0.68	--	2.3	0.030	2.3
4T2-6	--	--	0.125	0.030	0.130
4T2-7	--	--	0.175	0.010	0.180
4T2-8	--	--	0.100	0.020	0.120
4T2-9	--	--	0.125	0.020	0.100
4T2-10	--	--	0.100	0.020	0.110
4T2-11	--	--	0.075	0.020	0.120
4T2-12	--	--	0.050	0.020	0.140
4T2-13	--	--	0.125	0.020	0.120
4T2-14	1.13	--	3.9	0.030	1.86
4T4-4	--	--	0.150	0.020	0.050
4T4-5	1.24	0.20	5.0	0.190	2.7
4T4-6	0.188	--	0.58	0.020	0.21
4T4-7	--	--	0.150	0.020	0.150
4T4-8	--	--	0.20	0.020	0.160
4T4-9	--	--	0.23	0.010	0.080
4T4-10	--	--	0.175	0.010	0.010
4T4-11	--	0.125	9.5	0.25	4.3
4T4-12	2.1	0.125	10.8	0.170	3.0
4S1-1	-	-	-	--	--
4S2-1	-	-	-	--	--
4S3-1	-	-	-	--	--

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

- = site measurement point not established.

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

TABLE D-9. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Upland Flora and Soil Microflora Studies
Data Extrapolated to 150 Ampere Current

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations	
	NS	NEW	SEW	NS	EW
4C1-6	--	--	--	0.020	0.020
4C1-7	--	--	--	0.050	0.060
4C1-8	--	--	--	0.040	0.040
4C1-9	--	--	--	0.020	0.020
4C1-10	--	--	--	0.050	0.040
4C1-11	--	--	--	0.060	0.050
4C1-12	--	--	--	0.040	0.030
4C1-13	--	--	--	0.020	0.020
4T2-3	49	5.5	158	13.6	152
4T2-4	39	5.5	125	17.0	107
4T2-5	44	6.0	133	14.6	127
4T2-6	42	6.8	110	22	124
4T2-7	42	5.8	133	13.1	97
4T2-8	50	6.3	143	18.1	158
4T2-9	44	5.3	128	14.6	137
4T2-10	36	5.5	103	18.4	105
4T2-11	43	5.3	125	22	107
4T2-12	40	5.3	108	19.3	135
4T2-13	42	16.0	135	17.4	149
4T2-14	40	4.4	128	16.6	143
4T4-4	12.4	4.5	37	16.3	37
4T4-5	520	50	2000	140	1940
4T4-6	46	5.5	155	22	129
4T4-7	35	4.4	138	20	141
4T4-8	34	4.7	133	13.6	107
4T4-9	10.9	3.3	33	10.8	30
4T4-10	10.9	4.2	41	13.5	39
4T4-11	22	46	2200	107	1780
4T4-12	790	55	3000	138	2600
4S1-1	-	-	-	--	--
4S2-1	-	-	-	0.050	0.050
4S3-1	-	-	-	--	--

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

- = site measurement point not established.

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

TABLE D-10. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Upland Flora and Soil Microflora Studies
Data Extrapolated to 150 Ampere Current

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations	
	NS	NEW	SEW	NS	EW
4C1-6	--	--	--	--	--
4C1-7	--	--	--	--	--
4C1-8	--	--	--	--	--
4C1-9	--	--	--	--	--
4C1-10	--	--	--	--	--
4C1-11	--	--	--	--	--
4C1-12	--	--	--	--	--
4C1-13	--	--	--	--	--
4T2-3	1.76	0.025	5.5	0.080	5.5
4T2-4	1.84	0.025	6.0	0.080	5.7
4T2-5	7.4	--	25	0.110	24
4T2-6	2.2	0.025	11.0	0.060	11.6
4T2-7	1.73	0.025	5.5	0.060	5.9
4T2-8	1.69	0.025	5.5	0.060	5.9
4T2-9	1.09	0.025	3.5	0.070	3.8
4T2-10	1.24	0.025	3.7	0.060	3.9
4T2-11	1.61	0.025	5.3	0.060	5.6
4T2-12	1.76	0.025	5.8	0.060	6.1
4T2-13	3.2	--	10.8	0.050	11.4
4T2-14	7.9	--	26	0.120	25
4T4-4	0.71	--	2.4	0.050	2.4
4T4-5	4.3	0.025	14.3	0.080	14.0
4T4-6	1.69	0.025	5.5	0.080	5.3
4T4-7	1.43	0.025	4.7	0.080	4.5
4T4-8	1.31	0.025	4.5	0.070	4.3
4T4-9	0.94	5.3	3.0	0.050	2.9
4T4-10	0.83	--	2.9	0.050	2.7
4T4-11	6.0	0.025	20	0.110	18.9
4T4-12	4.3	0.025	14.5	0.100	13.7
4S1-1	-	-	-	--	--
4S2-1	-	-	-	--	--
4S3-1	-	-	-	--	--

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

- = site measurement point not established.

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

report. Other changes in the 60 Hz coupling may result from changes in power line loads or changes in earth conductivity as a function of soil moisture.

The EM fields generated by the 60 Hz current on the antenna wire are localized near the antenna and do not affect the 60 Hz fields at the control sites. In fact, all 60 Hz EM field measurements at the control sites for 1987 remained consistent with previous years' measurements.

In 1987, the 76 Hz longitudinal electric field and magnetic flux measured at the antenna and ground test sites during operation of the north-south antenna element were typically lower than those measured in 1986. The longitudinal electric field at the control, antenna, and ground sites were often below instrument detection levels, so similar comparisons could not be made for these fields.

All 76 Hz EM fields measured in 1987 during operation of the east-west antenna element at the antenna and ground sites were consistent with those measured in 1986 with the exception of the transverse electric field at the ground site, whose 1987 values were roughly one-half those measured in 1986. The fields measured during operation of the east-west antenna element dominated those measured during operation of the north-south element at test sites. At the control site, 76 Hz EM fields were often below the instrument detection level during operation of the east-west or north-south antenna elements.

Changes in the operational status of the MTF between 1986 and 1987 and their relationship to 76 Hz EM field intensities are discussed in Section 3.5.2.3 of this report.

The 60 Hz magnetic flux densities at the red maple leaf and pine needle collection sites were typically an order of magnitude greater than those measured at the study sites. The significance of this difference is not known, but consideration is being given to establishing new collection points that have lower ambient fields.

APPENDIX E
AQUATIC ECOSYSTEMS STUDIES

AQUATIC ECOSYSTEMS STUDIES

On 28 and 29 September 1987, IITRI field crews made ELF electromagnetic (EM) field measurements at 17 measurement points at a total of six test and four control sites for the aquatic ecosystems studies. The study sites and measurement points within the study sites were unchanged from 1986.

The positions of the 10 sites relative to the MTF are shown on the composite map in Figure E-1. The site numbers listed on the map are those used by IITRI. Table E-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. Details of measurement locations within sites are given in Figures E-2 through E-7.

The approach of the aquatic ecosystems studies is to integrate the major interrelated and interactive components of aquatic ecosystems (periphytic algae, aquatic insects, and fish) and to monitor events and processes critical to stream ecosystems. The electric field in the earth near the surface and the magnetic field are considered the most important factors influencing the aquatic ecosystems studies. The electric field in the air is not expected to have any impact on the components of these studies.

EM field measurements for 1987 and previous years are found in Tables E-2 through E-10. Tables E-2, E-3, and E-4 present 60 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Tables E-5, E-6, and E-7 present 76 Hz data for these three fields at 1986 and 1987 MTF operating currents. Tables E-8, E-9, and E-10 present 76 Hz data extrapolated to a full power condition of 150 amperes.

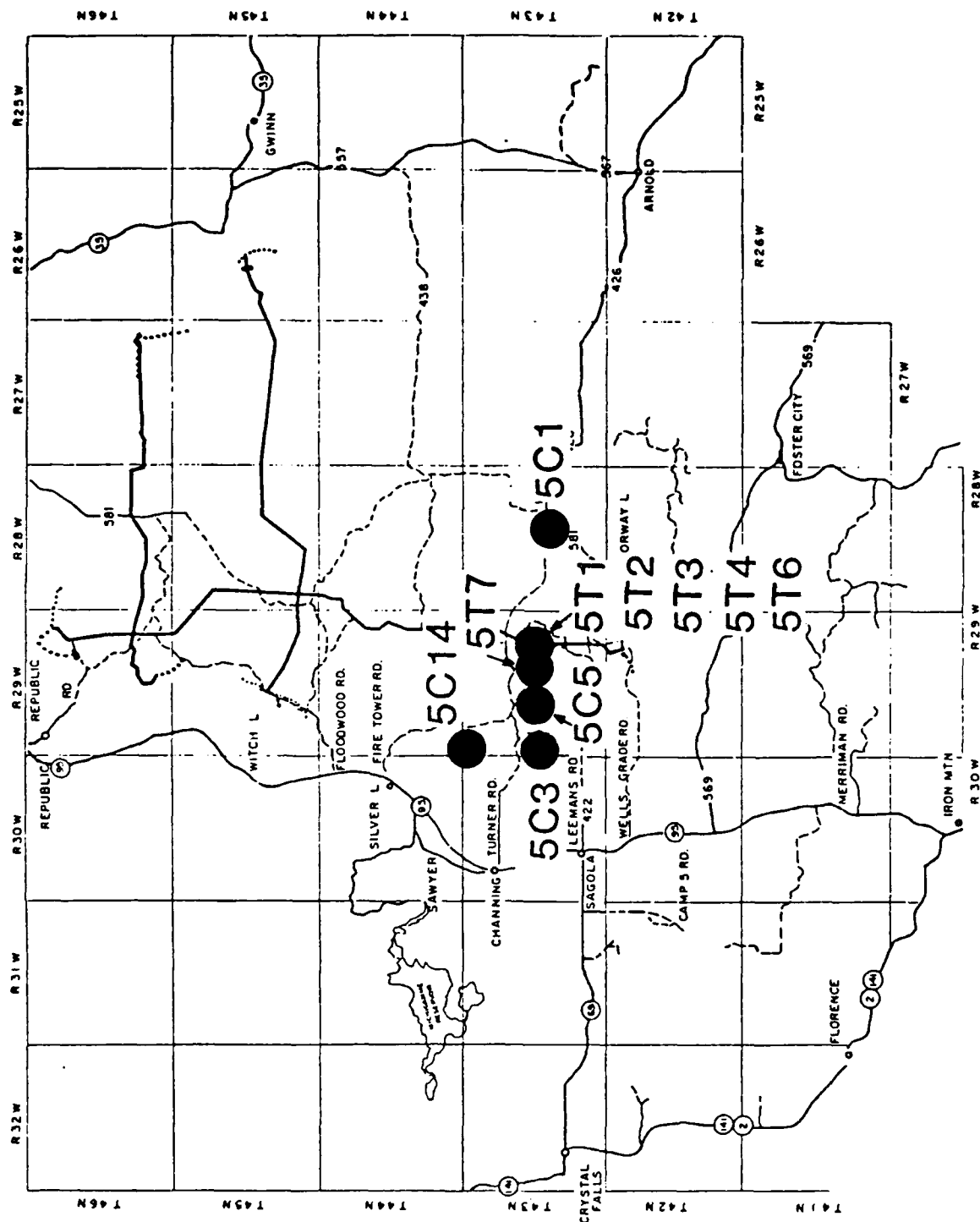
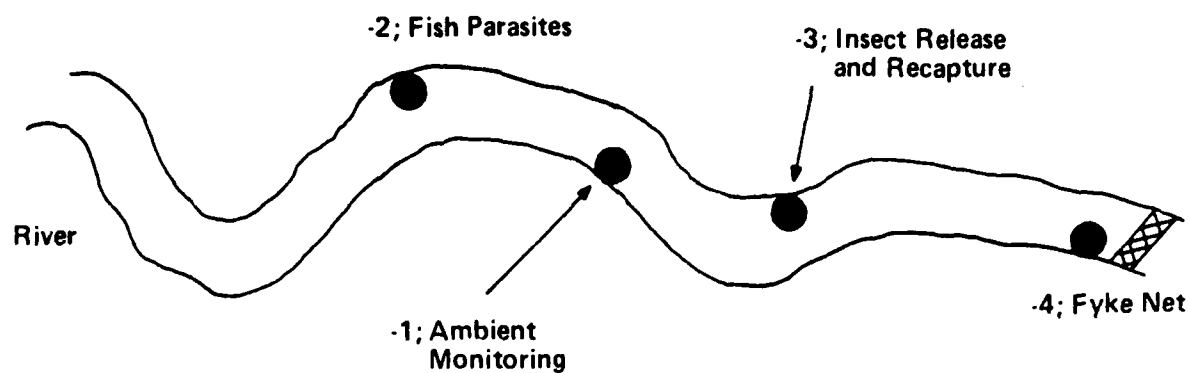


FIGURE E-1. POSITIONS OF AQUATIC ECOSYSTEMS STUDY SITES RELATIVE TO MICHIGAN TRANSMITTING FACILITY ANTENNA ELEMENTS.

TABLE E-1. SITE NO. CROSS-REFERENCE
Aquatic Ecosystems Studies

IITRI Site No.	Investigator's Site Name	Location		
		Township	: Range	: Section(s)
5T1-1	FEX 1; Fish Parasites	T43N	: R29W	: 11
5T1-2	FEX 1; Insect Substrates	T43N	: R29W	: 14
5T2-1	FEX 2; Ambient Monitoring	T43N	: R29W	: 14
5T2-2	FEX 2; Periphyton	T43N	: R29W	: 14
5T2-3	FEX 2; Insect Movement	T43N	: R29W	: 14
5T3-1	FEX 3; Fish Population	T43N	: R29W	: 14
5T4-1	FEX 4; Fish Parasites	T43N	: R29W	: 14
5T4-2	FEX 4; Fish Feeding	T43N	: R29W	: 14(11)
5T6-1	FEX 6; Fish Parasites	T43N	: R29W	: 13
5T7-1	FEX 7; Fish Population (future)	T43N	: R29W	: 14
5C1-1	FCD; Ambient Monitoring, Periphyton, Insect Substrates	T43N	: R28W	: 21
5C1-2	FCD; Fish Parasites	T43N	: R28W	: 21
5C1-3	FCD; Insect Movement	T43N	: R28W	: 21
5C1-4	FCD; Fish Population	T43N	: R28W	: 21
5C3-2	FCU; Fish Parasites, Fish Population	T43N	: R29W	: 18
5C5-1	FS1; Fish Population	T43N	: R29W	: 16
5C14-1	TM; Fish Population	T43N	: R29W	: 8



Not to Scale

FIGURE E-2. MEASUREMENT POINTS AT FCD; 5C1 - 1 THROUGH 4.

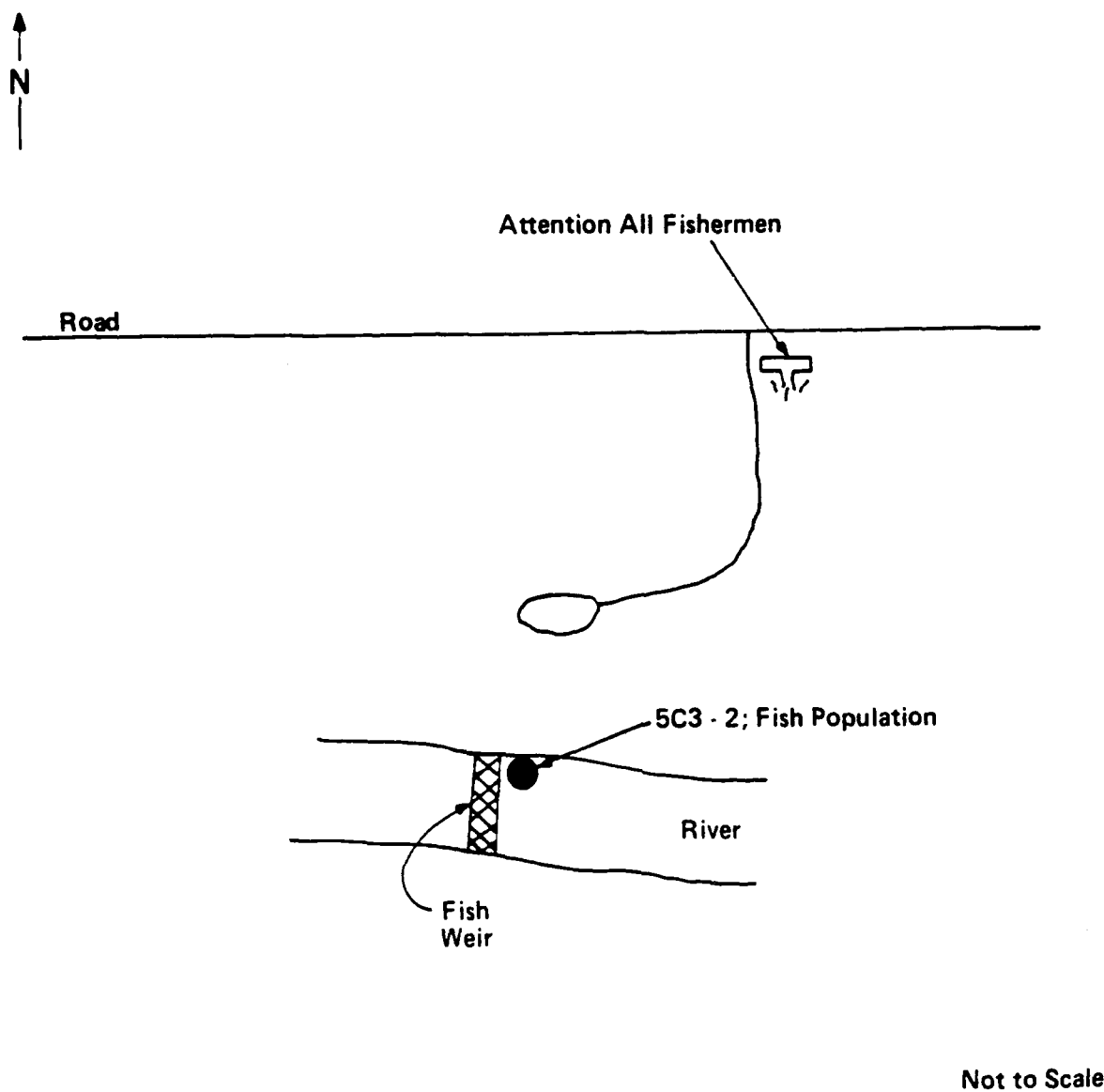
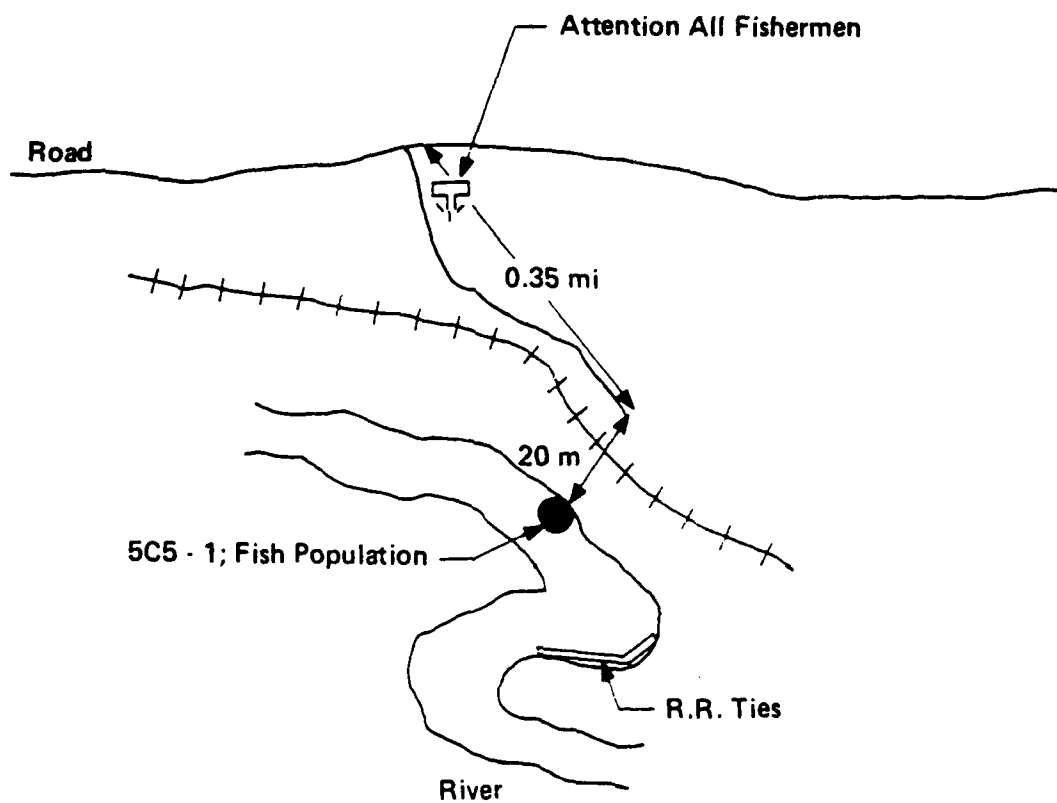
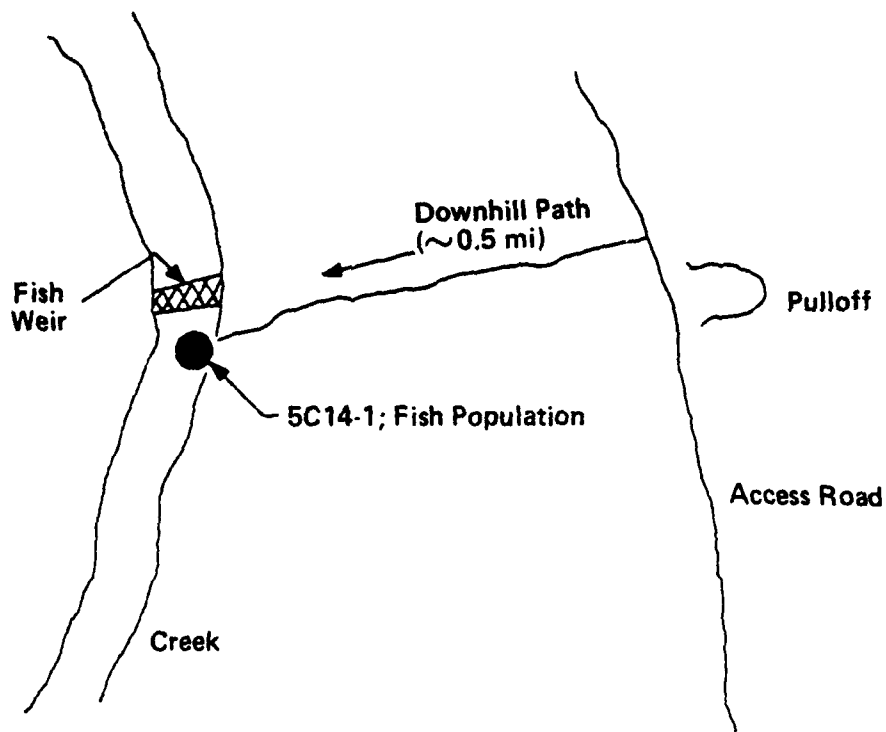
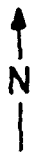


FIGURE E-3. MEASUREMENT POINT AT FCU; 5C3 -2.



Not to Scale

FIGURE E-4. MEASUREMENT POINT AT FS1; 5C5 - 1.



Not to Scale

FIGURE E-5. MEASUREMENT POINT AT TM; 5C14 - 1.

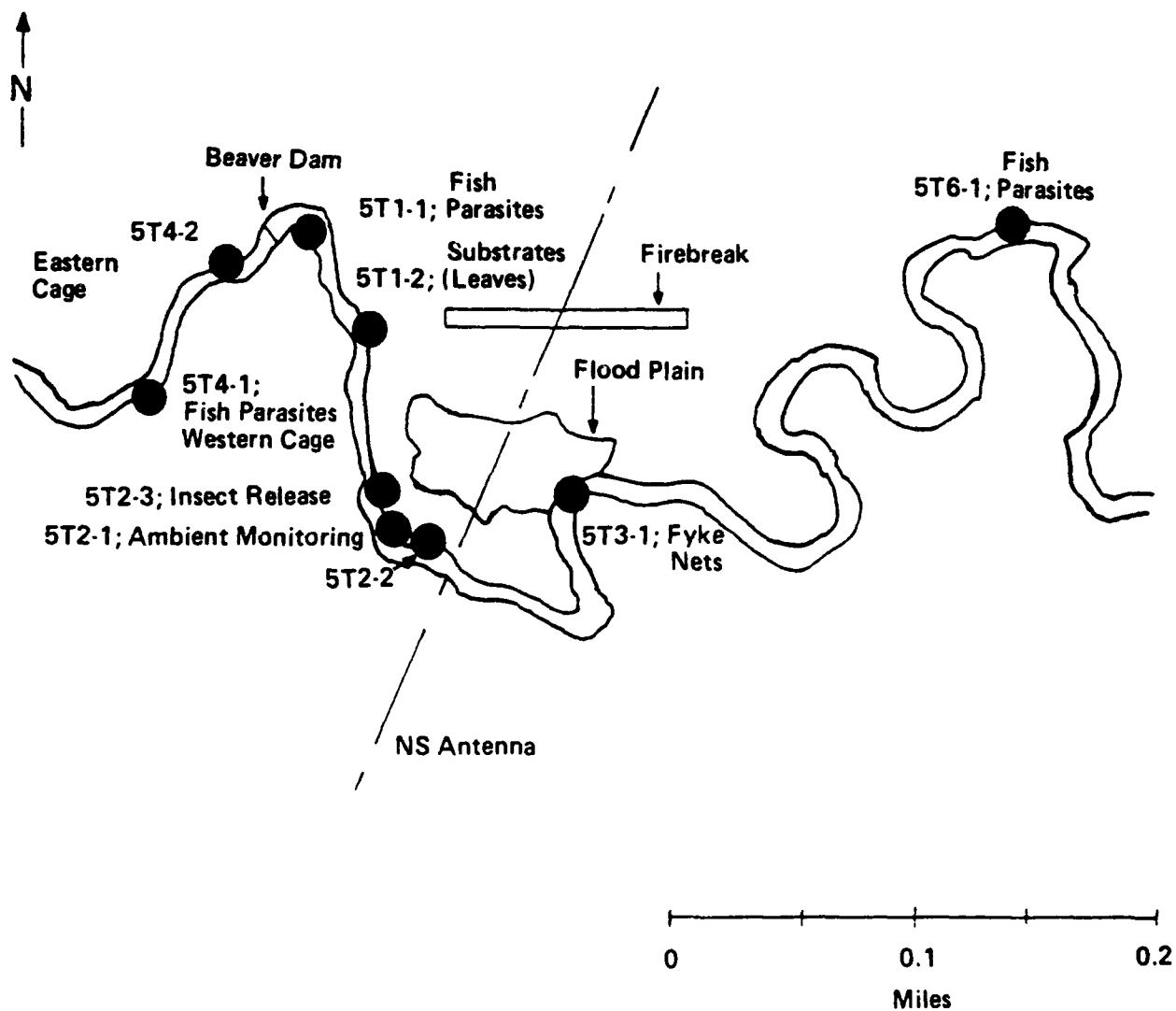
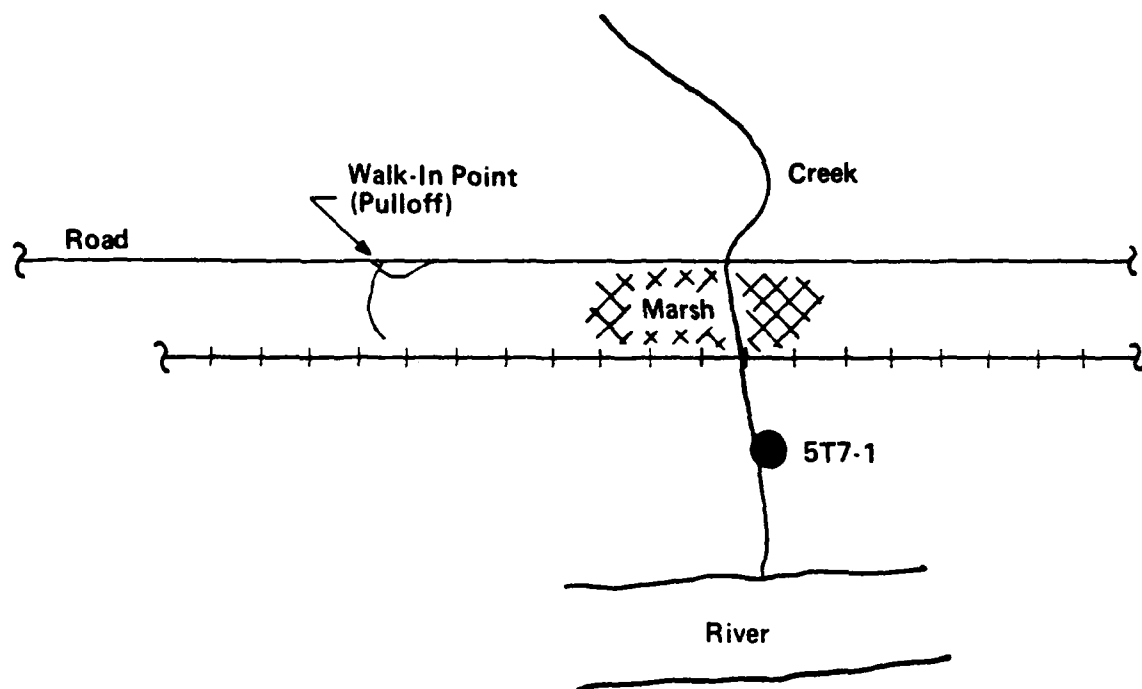


FIGURE E-6. MEASUREMENT POINTS AT FEX 1, FEX 2, FEX 3, FEX 4, FEX 6; 5T1 - 1, 2; 5T2 - 1, 2, 3; 5T3 - 1; 5T4 - 1, 2; 5T6 - 1.



Not to Scale

FIGURE E-7. MEASUREMENT POINT AT FEX 7; 5T7 - 1.

TABLE E-2. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Aquatic Ecosystems Studies

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c
5C1-1	0.002	<0.001	-	-	-
5C1-2	<0.001	/	/	-	-
5C1-3	<0.001	/	/	-	-
5C1-4	-	<0.001	-	-	-
5C3-2	<0.001	0.003	-	-	-
5C5-1	0.001	<0.001	-	-	-
5C14-1	-	0.033	-	-	-
5T1-1	-	/	/	-	-
5T1-2	<0.001	-	-	-	-
5T2-1	-	-	-	-	-
5T2-2	-	-	-	-	<0.001
5T2-3	-	-	-	-	-
5T3-1	-	-	-	-	0.001
5T4-1	-	-	/	-	-
5T4-2	-	-	-	-	-
5T6-1	-	<0.001	-	-	-
5T7-1	-	-	-	-	-

^a = prior to antenna construction.

^b = antenna elements grounded at transmitter (condition 2).

^c = antenna elements connected to transmitter, transmitter off (condition 9).

- = site measurement point not established.

- = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.

/ = data not taken.

TABLE E-3. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Aquatic Ecosystems Studies

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c
5C1-1	1.47,1.73	2.7	2.6	0.22	0.26
5C1-2	1.8	/	/	0.155	0.160
5C1-3	1.3	/	/	0.126	0.148
5C1-4	-	2.5,2.7	2.2	0.174	0.25
5C3-2	0.049	0.045	0.060	0.119	0.079
5C5-1	0.076	0.062	0.059	0.077	0.118
5C14-1	-	0.174,0.2	0.22	0.187	0.31
5T1-1	0.38	0.38	/	0.125	0.062
5T1-2	0.184	0.154,0.22	0.175	0.037	0.032
5T2-1	-	0.22,0.31	0.23	0.057	0.061
5T2-2	-	0.26	0.165	0.082	0.076
5T2-3	-	-	-	0.050	0.056
5T3-1	-	0.22,0.26	0.23	0.046	0.053
5T4-1	-	0.170,0.195	/	0.032	0.028
5T4-2	-	-	-	0.073	0.048
5T6-1	-	0.37,0.42	0.34	0.047	0.043
5T7-1	-	-	-	0.040	0.012

^a = prior to antenna construction.

^b = antenna elements grounded at transmitter (condition 2).

^c = antenna elements connected to transmitter, transmitter off (condition 9).

- = site measurement point not established.

/ = data not taken.

TABLE E-4. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Aquatic Ecosystems Studies

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c
5C1-1	0.008	0.008	0.003	0.001	0.001
5C1-2	0.006	/	/	0.001	0.001
5C1-3	0.004	/	/	0.001	0.001
5C1-4	-	0.007,0.008	0.007	0.001	0.001
5C3-2	0.003	0.003	0.003	0.005	0.004
5C5-1	0.002	0.002	0.002	0.001	0.001
5C14-1	-	0.013,0.021	0.020	0.017	0.094
5T1-1	<0.001	<0.001	/	0.002	0.003
5T1-2	<0.001	0.001	0.001	0.004	0.005
5T2-1	-	0.001,0.002	0.001	0.005	0.009
5T2-2	-	0.002	0.001	0.014	0.021
5T2-3	-	-	-	0.004	0.007
5T3-1	-	0.001,0.002	0.001	0.005	0.009
5T4-1	-	0.001	/	<0.001	0.002
5T4-2	-	-	-	0.001	0.002
5T6-1	-	0.001	0.001	0.001	0.002
5T7-1	-	-	-	0.001	0.001

^a = prior to antenna construction.

^b = antenna elements grounded at transmitter (condition 2).

^c = antenna elements connected to transmitter, transmitter off (condition 9).

- = site measurement point not established.

/ = data not taken.

TABLE E-5. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Aquatic Ecosystems Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M
5C1-1	-	-	-	--	-	-
5C1-2	-	-	-	--	-	-
5C1-3	-	-	-	--	-	-
5C1-4	-	-	-	--	-	-
5C3-2	-	-	-	--	-	-
5C5-1	-	-	-	--	-	-
5C14-1	-	-	-	--	-	-
5T1-1	-	-	-	--	0.009	-
5T1-2	-	-	-	--	<0.001	-
5T2-1	0.001	-	-	--	0.005	-
5T2-2	0.011	-	-	--	0.022	<0.001
5T2-3	-	-	-	--	0.005	-
5T3-1	0.008	-	-	--	0.020	-
5T4-1	-	-	-	--	0.003	-
5T4-2	-	-	-	--	0.007	-
5T6-1	-	-	-	--	0.006	-
5T7-1	-	-	-	--	/	-

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

- = measurement expected to be <0.001 based on the longitudinal electric field measurement.

-- = data cannot be extrapolated.

/ = data not taken.

TABLE E-6. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Aquatic Ecosystems Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M
5C1-1	0.33	0.020	0.052	0.087	1.33	0.158
5C1-2	0.24	0.016	0.053	0.088	1.07	0.186
5C1-3	0.191	0.013	0.047	0.078	0.85	0.130
5C1-4	0.26	0.014	0.075	0.125	1.02	0.160
5C3-2	0.013	0.002	0.007	0.012	0.067	0.023
5C5-1	0.034	0.002	0.009	0.015	0.138	0.035
5C14-1	0.042	0.004	0.015	0.025	0.183	0.055
5T1-1	2.5	0.080	0.108	0.180	7.5	0.33
5T1-2	0.77	0.034	0.097	0.162	2.9	0.30
5T2-1	1.33	0.045	0.077	0.128	5.4	0.22
5T2-2	1.62	0.052	0.067	0.112	6.1	0.184
5T2-3	1.17	0.042	0.079	0.132	4.9	0.23
5T3-1	1.22	0.045	0.082	0.137	4.8	0.27
5T4-1	0.75	0.026	0.061	0.102	3.0	0.182
5T4-2	1.91	0.056	0.077	0.128	5.3	0.21
5T6-1	1.21	0.030	0.066	0.110	4.5	0.20
5T7-1	0.76	0.033	0.072	0.120	2.6	0.189

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

TABLE E-7. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Aquatic Ecosystems Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M
5C1-1	0.001	<0.001	<0.001	--	0.005	0.001
5C1-2	0.001	<0.001	<0.001	--	0.005	0.001
5C1-3	0.001	<0.001	<0.001	--	0.005	0.001
5C1-4	0.001	<0.001	<0.001	--	0.005	0.001
5C3-2	0.001	<0.001	<0.001	--	0.003	0.001
5C5-1	0.003	<0.001	0.001	0.002	0.013	0.002
5C14-1	0.001	<0.001	<0.001	--	0.005	0.001
5T1-1	0.045	0.001	<0.001	--	0.170	0.002
5T1-2	0.063	0.002	<0.001	--	0.25	0.002
5T2-1	0.129	0.004	0.001	0.002	0.50	0.002
5T2-2	0.31	0.009	0.001	0.002	1.20	0.003
5T2-3	0.110	0.003	--	--	0.41	0.002
5T3-1	0.137	0.004	0.001	0.002	0.51	0.001
5T4-1	0.028	0.001	<0.001	--	0.118	0.002
5T4-2	0.033	0.001	<0.001	--	0.123	0.002
5T6-1	0.029	0.001	0.001	0.002	0.109	0.002
5T7-1	0.011	<0.001	0.001	0.002	0.040	0.002

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

-- = measurement expected to be <0.001 based on the longitudinal electric field measurements.

-- = data cannot be extrapolated.

TABLE E-8. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Aquatic Ecosystems Studies
Data Extrapolated to 150 Ampere Current

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations	
	NS	NEW	SEW	NS	EW
5C1-1	--	--	--	--	--
5C1-2	--	--	--	--	--
5C1-3	--	--	--	--	--
5C1-4	--	--	--	--	--
5C3-2	--	--	--	--	--
5C5-1	--	--	--	--	--
5C14-1	--	--	--	--	--
5T1-1	--	--	--	0.090	--
5T1-2	--	--	--	--	--
5T2-1	0.038	--	--	0.050	--
5T2-2	0.41	--	--	0.22	--
5T2-3	--	--	--	0.050	--
5T3-1	0.30	--	--	0.20	--
5T4-1	--	--	--	0.030	--
5T4-2	--	--	--	0.070	--
5T6-1	--	--	--	0.060	--
5T7-1	--	--	--	/	--

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

/ = data not taken.

TABLE E-9. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Aquatic Ecosystems Studies
Data Extrapolated to 150 Ampere Current

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations	
	NS	NEW	SEW	NS	EW
5C1-1	12.4	0.50	1.30	13.3	1.58
5C1-2	9.0	0.40	1.33	10.7	1.86
5C1-3	7.2	0.33	1.18	8.5	1.30
5C1-4	9.8	0.35	1.88	10.2	1.60
5C3-2	0.49	0.050	0.175	0.67	0.23
5C5-1	1.28	0.050	0.23	1.38	0.35
5C14-1	1.58	0.100	0.38	1.83	0.55
5T1-1	94	2.0	2.7	75	3.3
5T1-2	29	0.85	2.4	29	3.0
5T2-1	50	1.13	1.93	54	2.2
5T2-2	61	1.30	1.68	61	1.84
5T2-3	44	1.05	1.98	49	2.3
5T3-1	46	1.13	2.1	48	2.7
5T4-1	28	0.65	1.53	30	1.82
5T4-2	72	1.40	1.93	53	2.1
5T6-1	45	0.75	1.65	45	2.0
5T7-1	29	0.83	1.80	26	1.89

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

TABLE E-10. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Aquatic Ecosystems Studies
Data Extrapolated to 150 Ampere Current

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations	
	NS	NEW	SEW	NS	EW
5C1-1	0.038	--	--	0.050	0.010
5C1-2	0.038	--	--	0.050	0.010
5C1-3	0.038	--	--	0.050	0.010
5C1-4	0.038	--	--	0.050	0.010
5C3-2	0.038	--	--	0.030	0.010
5C5-1	0.113	--	0.025	0.130	0.020
5C14-1	0.038	--	--	0.050	0.010
5T1-1	1.69	0.025	--	1.70	0.020
5T1-2	2.4	0.050	--	2.5	0.020
5T2-1	4.8	0.100	0.025	5.0	0.020
5T2-2	11.6	0.23	0.025	12.0	0.030
5T2-3	4.1	0.075	--	4.1	0.020
5T3-1	5.1	0.100	0.025	5.1	0.010
5T4-1	1.05	0.025	--	1.18	0.020
5T4-2	1.24	0.025	--	1.23	0.020
5T6-1	1.09	0.025	0.025	1.09	0.020
5T7-1	0.41	--	0.025	0.40	0.020

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

The 1987 60 Hz measurements at test sites showed the same general trends in field magnitudes as were reported in 1986 as the result of 60 Hz signals from power lines coupled onto the ELF antenna elements. That is, the 60 Hz magnetic flux densities increased and the longitudinal electric fields decreased near the antenna wires in comparison to measurements made prior to antenna construction. However, 1987 60 Hz magnetic field levels at sites 5T2, 5T3, 5T4, and 5T6 were about two times greater than those measured in 1986. This is likely the result of several factors. For example, the antenna elements were not grounded at the transmitters during the 60 Hz measurements in 1987 as they were in 1986. This may change the amount of 60 Hz coupling to the antenna elements, as is explained in Section 3.5.2.2 of this report. Other changes in the 60 Hz coupling may result from changes in power line loads.

The EM fields generated by the 60 Hz current on the antenna wire are localized near the antenna and do not affect the 60 Hz fields at the control sites. All 60 Hz EM field measurements at the control sites for 1987 remained consistent with previous years' measurements, with the exception of the magnetic flux density at 5C14-1, which increased by more than a factor of five. This difference may reflect a change in the load current of the 138 kV transmission line immediately to the west.

In 1987, the 76 Hz longitudinal electric field and magnetic flux measured at test sites during operation of the east-west antenna element were consistently lower than those measured in 1986. The longitudinal electric field at control sites changed little between 1986 and 1987 during the operation of the east-west antenna element. The magnetic flux density at control sites and the transverse electric field at both test and control sites were often below the instrument detection level, so similar comparisons could not be made for these fields.

All 76 Hz EM fields measured at test sites in 1987 during operation of the north-south antenna element remained consistent with those measured in 1986. The longitudinal electric field and magnetic flux rose about 10% and 25%, respectively, at control sites during operation of the north-south antenna element.

Changes in the operational status of the MTF between 1986 and 1987 and their relationship to 76 Hz EM field intensities are discussed in Section 3.5.2.3 of this report.

APPENDIX F
SOIL AMOEBA STUDIES

SOIL AMOEBA STUDIES

On 30 September and 1 and 2 October 1987, IITRI field crews made ELF electromagnetic (EM) field measurements at nine measurement points at a total of two test sites and one control site for the soil amoeba studies. The study sites and measurement points within the study sites were unchanged from 1986.

The positions of the three sites relative to the MTF are shown on the composite map in Figure F-1. The site numbers listed on the map are those used by IITRI. Table F-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites. Details of measurement locations within sites are shown in Figures F-2 through F-4.

The objectives of these studies are to monitor population and species characteristics, cell cycle, cropping efficiency, and distribution in the soil. The electric and magnetic fields in the earth are considered the most important EM factors to be examined. The electric field in the air is not expected to have a significant impact on the objectives of these studies.

Several of the above objectives require the use of buried culture chambers at the study sites. The chambers are used to match the internal EM fields of the cultures to those present in the surrounding earth.

EM field measurements for 1987 and previous years are found in Tables F-2 through F-10. Tables F-2, F-3, and F-4 present 60 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Tables F-5, F-6, and F-7 present 76 Hz data for these three fields at 1986 and 1987 MTF operating currents. Tables F-8, F-9, and F-10 present 76 Hz data extrapolated to a full power condition of 150 amperes.

TABLE F-1. SITE NO. CROSS-REFERENCE
Soil Amoeba Studies

IITRI Site No.	Investigator's Site Name	Location		
		Township	: Range	: Section(s)
6T3	Leeman's Road--New	T43N	: R29W	: 23
6T4	Wells Grade Ground	T42N	: R29W	: 2
6C2	Merriman Truck Trail Control	T41N	: R29W	: 21

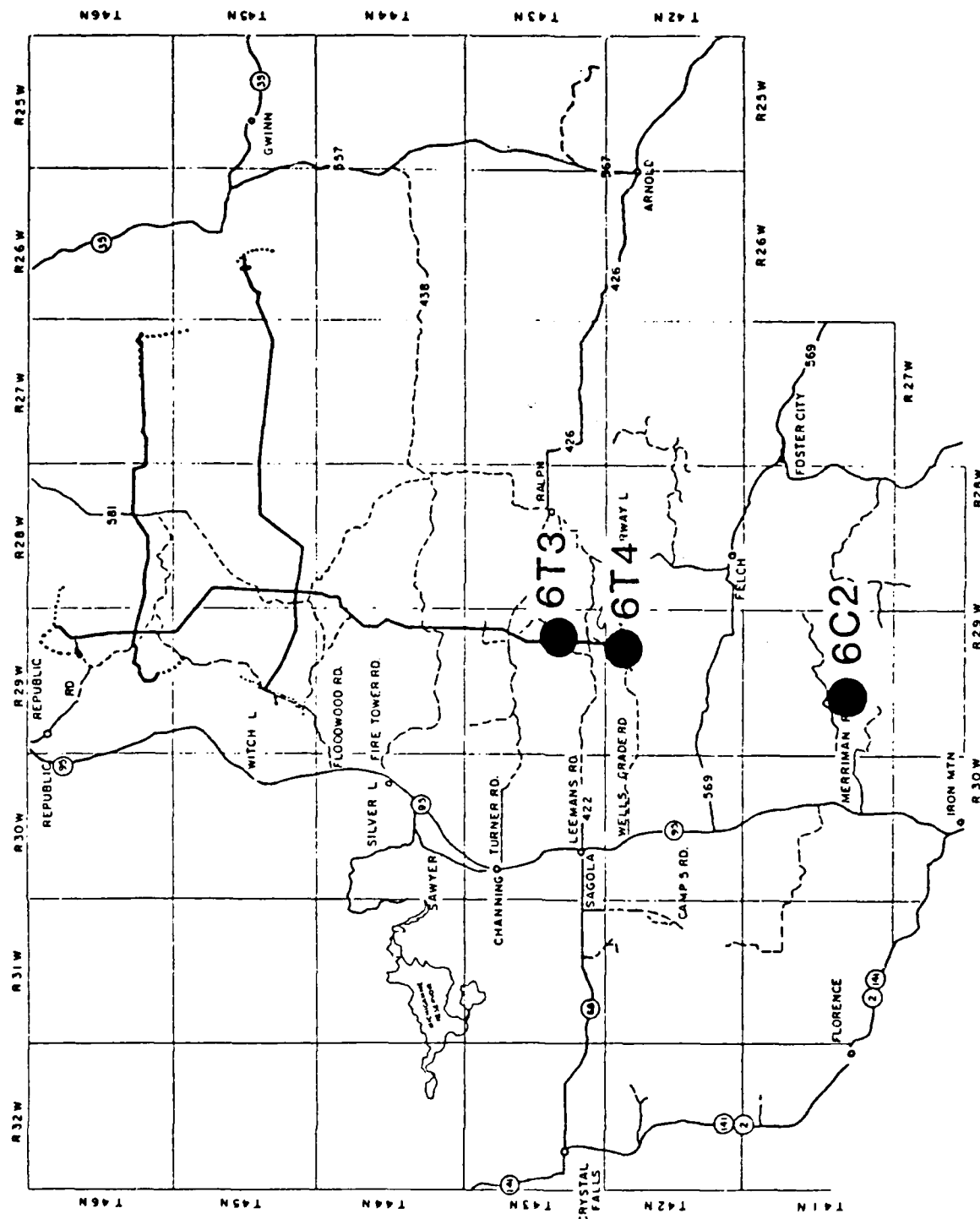


FIGURE F-1. POSITIONS OF SOIL AMOEBA STUDY SITES RELATIVE TO MICHIGAN TRANSMITTING FACILITY ANTENNA ELEMENTS.

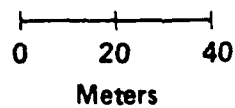
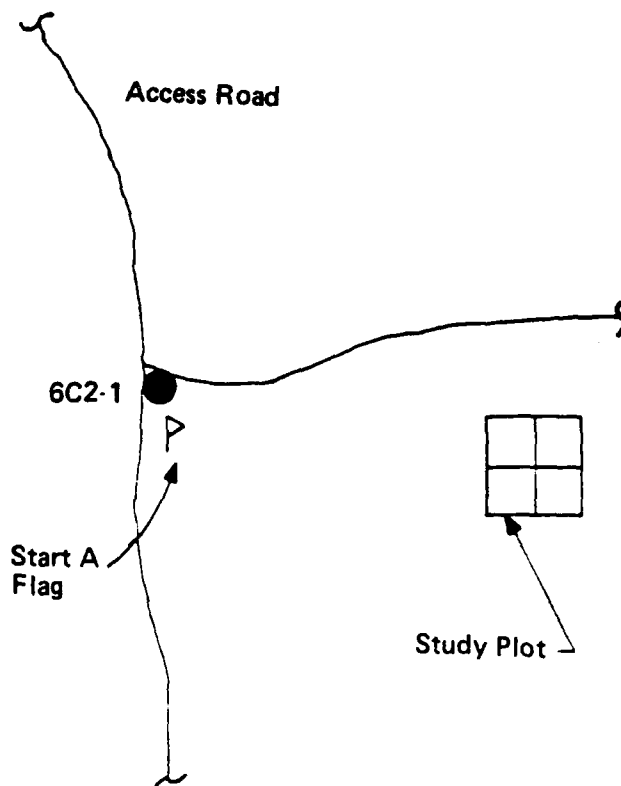
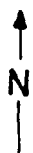


FIGURE F-2. MEASUREMENT POINT AT MERRIMAN TRUCK TRAIL CONTROL; 6C2 - 1.

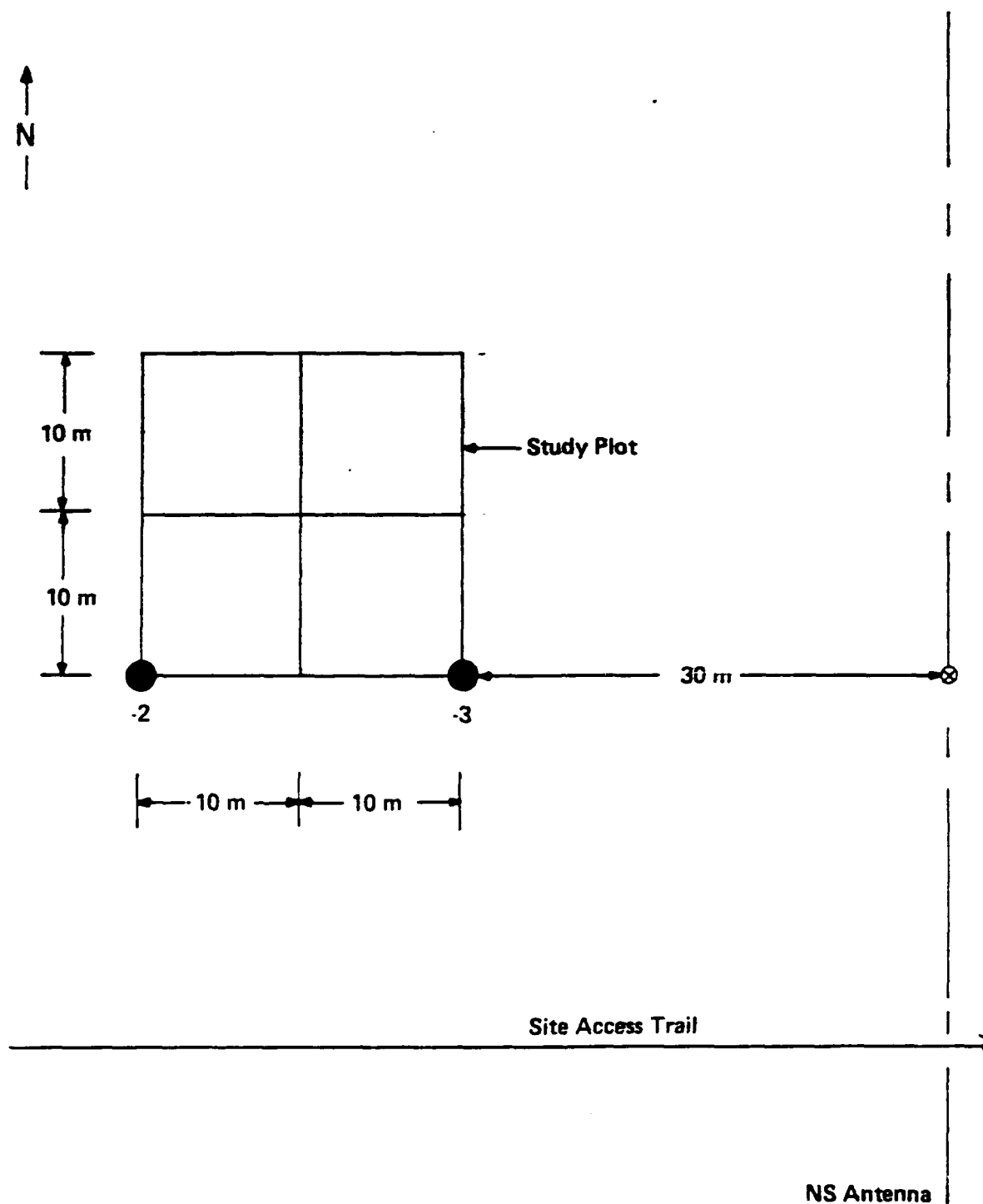


FIGURE F-3. MEASUREMENT POINTS AT LEEMAN'S ROAD; 6T3 - 2, 3.

↑
N

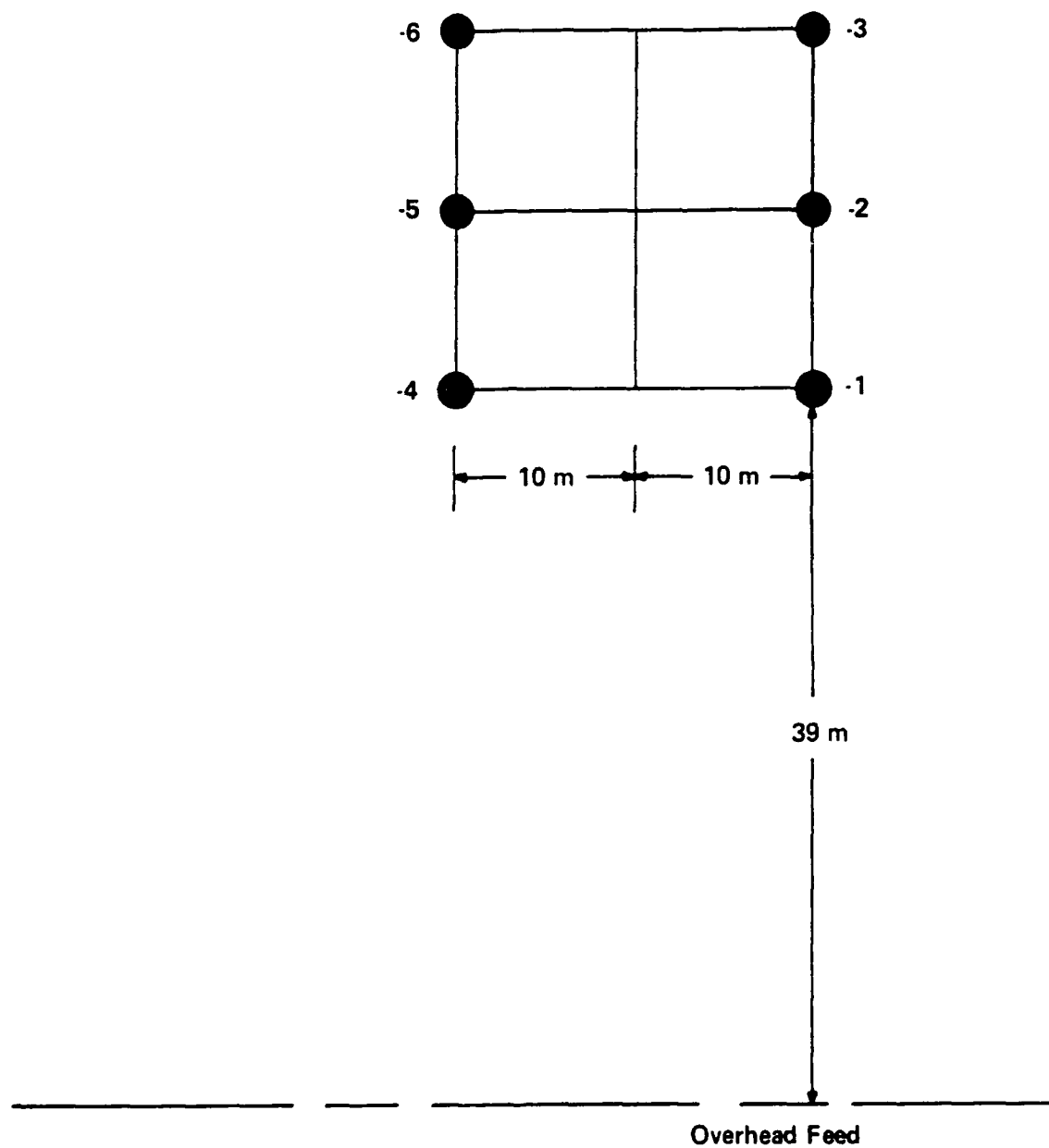


FIGURE F-4. MEASUREMENT POINTS AT WELLS GRADE GROUND; 6T4 - 1 THROUGH 6.

TABLE F-2. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Soil Amoeba Studies

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c
6C2-1	<0.001	-	-	-	-
6T3-2	-	-	-	-	-
6T3-3	-	-	-	-	-
6T4-1	-	-	-	-	-
6T4-2	-	-	-	-	-
6T4-3	-	-	-	-	-
6T4-4	-	-	-	-	-
6T4-5	-	-	-	-	-
6T4-6	-	-	-	-	-

^a = prior to antenna construction.

^b = antenna elements grounded at transmitter (condition 2).

^c = antenna elements connected to transmitter, transmitter off (condition 9).

- = site measurement point not established.

- = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.

TABLE F-3. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Soil Amoeba Studies

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c
6C2-1	0.32	0.61	0.194,0.28	0.058	0.256
6T3-2	0.087	0.130	/	0.085	0.125
6T3-3	-	-	0.134	0.078	0.130
6T4-1	-	0.48,0.52	/	0.072	0.32
6T4-2	-	-	-	0.046	0.162
6T4-3	-	-	-	0.065	0.082
6T4-4	-	-	-	0.037	0.24
6T4-5	-	-	-	0.053	0.182
6T4-6	-	-	-	0.098	0.084

^a = prior to antenna construction.

^b = antenna elements grounded at transmitter (condition 2).

^c = antenna elements connected to transmitter, transmitter off (condition 9).

- = site measurement point not established.

/ = data not taken.

**TABLE F-4. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Amoeba Studies**

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c
6C2-1	0.004	0.008	0.001,0.003	0.002	0.003
6T3-2	-	0.002	/	0.020	0.023
6T3-3	-	-	0.003	0.013	0.033
6T4-1	-	0.005,0.007	/	0.005	0.006
6T4-2	-	-	-	0.005	0.006
6T4-3	-	-	-	0.004	0.005
6T4-4	-	-	-	0.002	0.006
6T4-5	-	-	-	0.003	0.006
6T4-6	-	-	-	0.005	0.005

^a = prior to antenna construction.

^b = antenna elements grounded at transmitter (condition 2).

^c = antenna elements connected to transmitter, transmitter off (condition 9).

- = site measurement point not established.

/ = data not taken.

**TABLE F-5. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Soil Amoeba Studies
Measured (M) and Extrapolated (Ex) Data**

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M
6C2-1	-	-	-	--	-	-
6T3-2	-	-	-	--	0.005	-
6T3-3	-	-	-	--	0.005	-
6T4-1	-	-	-	--	0.020	-
6T4-2	-	-	-	--	0.007	-
6T4-3	-	-	-	--	0.004	-
6T4-4	-	-	-	--	0.014	-
6T4-5	-	-	-	--	0.007	-
6T4-6	-	-	-	--	0.004	-

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

- = measurement expected to be <0.001 based on the longitudinal electric field measurement.

-- = data cannot be extrapolated.

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TABLE F-6. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Soil Amoeba Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M
6C2-1	0.028	0.010	0.011	0.018	0.068	0.028
6T3-2	1.34	0.041	0.030	0.050	5.4	0.087
6T3-3	1.45	0.046	0.040	0.067	5.9	0.110
6T4-1	1.73	0.059	0.007	0.012	18.9	0.056
6T4-2	0.72	0.023	0.009	0.015	8.5	0.038
6T4-3	1.14	0.035	0.018	0.030	4.3	0.031
6T4-4	1.31	0.042	0.006	0.010	12.8	0.040
6T4-5	0.78	0.027	0.012	0.020	10.2	0.045
6T4-6	1.27	0.040	0.015	0.025	4.4	0.034

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

TABLE F-7. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Amoeba Studies
Measured (M) and Extrapolated (Ex) Data

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M
6C2-1	<0.001	<0.001	<0.001	--	<0.001	<0.001
6T3-2	0.170	0.006	0.001	0.002	0.64	0.003
6T3-3	0.28	0.009	0.001	0.002	1.03	0.004
6T4-1	0.100	0.003	0.001	0.002	0.35	0.001
6T4-2	0.082	0.003	0.001	0.002	0.29	0.001
6T4-3	0.071	0.002	<0.001	--	0.26	0.001
6T4-4	0.090	0.003	0.001	0.002	0.38	0.001
6T4-5	0.078	0.002	<0.001	--	0.27	<0.001
6T4-6	0.067	0.002	<0.001	--	0.24	0.001

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

-- = data cannot be extrapolated.

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TABLE F-8. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Soil Amoeba Studies
Data Extrapolated to 150 Ampere Current

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations	
	NS	NEW	SEW	NS	EW
6C2-1	--	--	--	--	--
6T3-2	--	--	--	0.050	--
6T3-3	--	--	--	0.050	--
6T4-1	--	--	--	0.20	--
6T4-2	--	--	--	0.070	--
6T4-3	--	--	--	0.040	--
6T4-4	--	--	--	0.140	--
6T4-5	--	--	--	0.070	--
6T4-6	--	--	--	0.040	--

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

TABLE F-9. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Soil Amoeba Studies
Data Extrapolated to 150 Ampere Current

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations	
	NS	NEW	SEW	NS	EW
6C2-1	1.05	0.25	0.28	0.68	0.28
6T3-2	50	1.03	0.75	54	0.87
6T3-3	54	1.15	1.00	59	1.10
6T4-1	65	1.48	0.175	189	0.56
6T4-2	27	0.58	0.23	85	0.38
6T4-3	43	0.88	0.45	43	0.31
6T4-4	49	1.05	0.150	128	0.40
6T4-5	29	0.68	0.30	102	0.45
6T4-6	48	1.00	0.38	44	0.34

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

TABLE F-10. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Soil Amoeba Studies
Data Extrapolated to 150 Ampere Current

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations	
	NS	NEW	SEW	NS	EW
6C2-1	--	--	--	--	--
6T3-2	6.4	0.150	0.025	6.4	0.030
6T3-3	10.5	0.23	0.025	10.3	0.040
6T4-1	3.8	0.075	0.025	3.5	0.010
6T4-2	3.1	0.075	0.025	2.9	0.010
6T4-3	2.7	0.050	--	2.6	0.010
6T4-4	3.4	0.075	0.025	3.8	0.010
6T4-5	2.9	0.050	--	2.7	--
6T4-6	2.5	0.050	--	2.4	0.010

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

The 1987 60 Hz measurements at the antenna sites showed the same general trends in field magnitudes as was reported in 1986 as the result of 60 Hz signals from power lines coupled onto the ELF antenna elements. That is, the 60 Hz magnetic flux densities increased and the 60 Hz longitudinal electric field intensities decreased near the antenna wires in comparison to measurements made prior to antenna construction. The magnetic flux densities at the control site and ground test site have remained relatively constant over the years of measurement. The 60 Hz longitudinal electric field increased noticeably at all three study sites between 1986 and 1987. In view of the small changes in the magnetic flux density, this is likely the result of changes in earth conductivity relating to soil moisture content.

In 1987, the 76 Hz longitudinal electric field and magnetic flux measured at the control, test, and ground sites during operation of the east-west antenna element were consistently lower than those measured in 1986. The 76 Hz transverse electric field at the control, test, and ground sites was often below the instrument detection level, so similar comparisons could not be made.

All of the 1987 76 Hz magnetic flux measurements made during operation of the north-south antenna element were consistent with those made in 1986. The 1987 76 Hz longitudinal electric field measurements at the ground site during operation of the north-south antenna element were about three times lower than those measured in 1986 at the four measurement points closest to the antenna ground element. The 1987 76 Hz longitudinal electric fields measured under the same conditions at the two points furthest from the antenna ground element were consistent with 1986 measurements. The 76 Hz longitudinal electric fields measured at the antenna and control site during operation of the north-south antenna element were within the expected variation between 1986 and 1987.

Changes in the operational status of the MTF between 1986 and 1987 and their relationship to 76 Hz EM field intensities are discussed in Section 3.5.2.3 of this report.

APPENDIX G
SLIME MOLD STUDIES

SLIME MOLD STUDIES

On 20 and 21 August 1987, IITRI field crews made ELF electromagnetic (EM) field measurements at nine measurement points at a total of two test sites and one control site for the slime mold studies. The study sites and measurement points within the study sites were unchanged from 1986.

The positions of the three sites relative to the WTF are shown on the composite map in Figure G-1. The site numbers listed on the map are those used by IITRI. Table G-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites.

TABLE G-1. SITE NO. CROSS-REFERENCE
Slime Mold Studies

IITRI Site No.	Investigator's Site Name	Location		
		Township	: Range	: Section(s)
7A2	Antenna No. 2	T42N	: R5W	: 7
7C1	Control No. 1	T43N	: R2W	: 31
7G3	Ground No. 3	T42N	: R5W	: 7

The slime mold studies have been designed to monitor for ELF EM field exposure effects on the respiration and mitosis of the slime mold, Physarum polycephalum. The electric and magnetic fields in the earth are considered important EM factors influencing soil biota. The electric field in the air is not expected to have a significant impact on the objectives of these studies.

Several of the above objectives require the use of buried culture chambers at the study sites. These chambers are used to match the internal EM fields of the cultures to those present in the surrounding earth.

Tables G-2, G-3, and G-4 present a summary of 76 Hz transverse electric field intensities, longitudinal electric field intensities, and magnetic flux densities, respectively, as measured at the study sites. Data for 1987 are

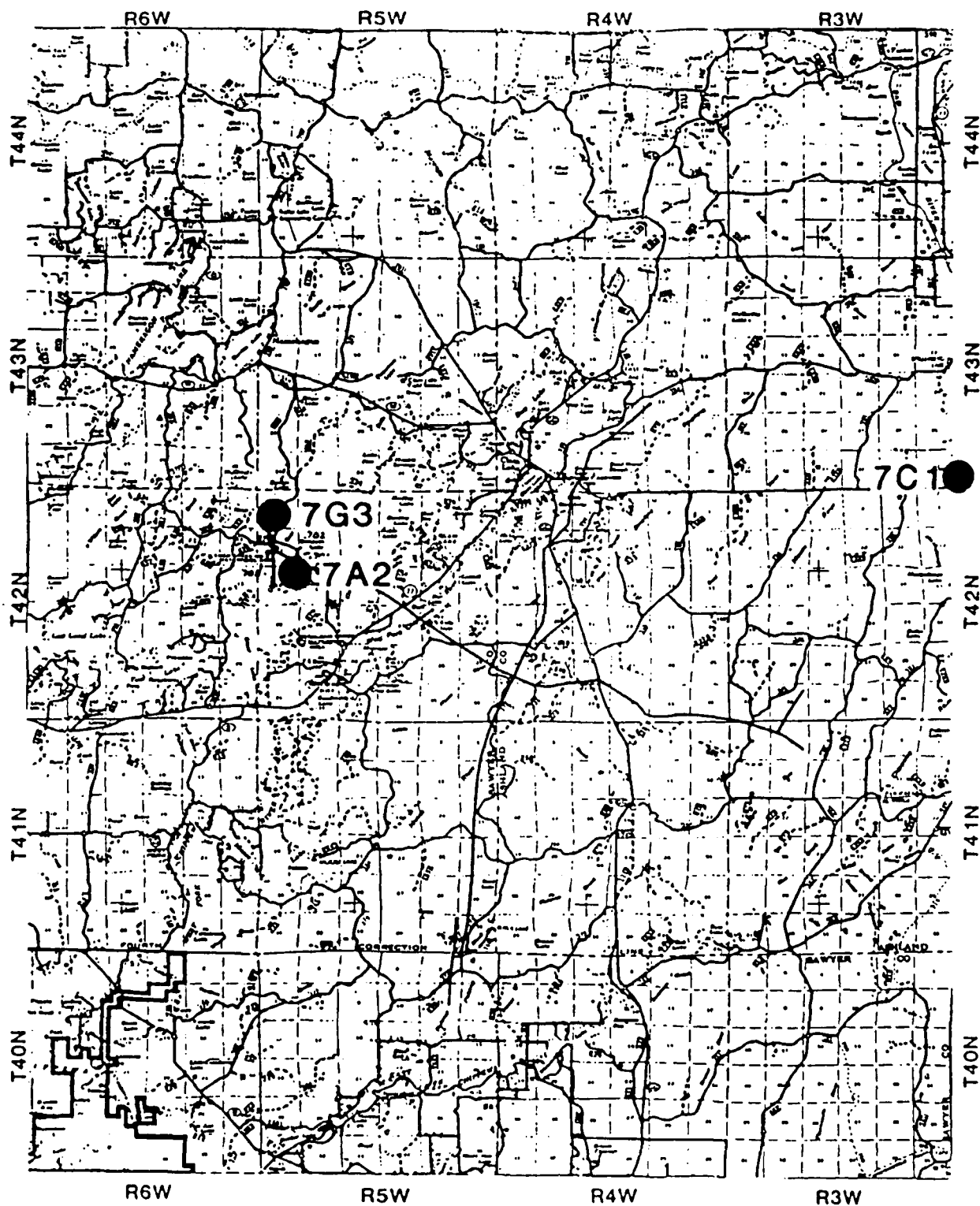


FIGURE G-1. POSITIONS OF SLIME MOLD STUDY SITES RELATIVE TO WISCONSIN TRANSMITTING FACILITY ANTENNA ELEMENTS.

TABLE G-2. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Slime Mold Studies

Site No., Meas. Pt.	1982		1983		1984		1985			1986	1987
	NS	EW	NS	EW	NS	EW	NS	EW	B(-75)	B(-75)	B(-75)
7A2-C	-	-	-	-	0.004	0.031	/	/	/	/	/
7A2-N	-	-	-	-	-	-	/	/	/	/	/
7A2-S	-	-	-	-	-	-	/	/	/	/	/
7C1-C	/	/	/	/	/	/	/	/	/	/	/
7C1-N	-	-	-	-	-	-	/	/	/	/	/
7C1-S	-	-	-	-	-	-	/	/	/	/	/
7G3-C	-	-	/	/	0.014	1.49	/	/	/	/	/
7G3-N	-	-	-	-	-	-	/	/	/	/	/
7G3-S	-	-	-	-	-	-	/	/	/	/	/

NS = north-south antenna.
EW = east-west antenna.
B = both antennas.
- = site not established.
/ = data not taken.

TABLE G-3. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Slime Mold Studies

Site No., Meas. Pt.	1982		1983		1984		1985			1986	1987
	NS	EW	NS	EW	NS	EW	NS	EW	B(-75)	B(-75)	B(-75)
7A2-C	-	-	-	-	3.9, 4.1	200, 240	/	189, 210	200, 220	240	207
7A2-N	-	-	-	-	-	-	/	210	/	220	205
7A2-S	-	-	-	-	-	-	/	200	/	156	169
7C1-C	0.95	0.97	0.96	0.96	1.11	1.13	0.90	/	1.17	1.20	1.04
7C1-N	-	-	-	-	-	-	1.03	/	/	1.38	1.41
7C1-S	-	-	-	-	-	-	1.00	/	/	1.35	1.20
7G3-C	-	-	18	1840	13.3	1460	/	610, 780	570	1000	498
7G3-N	-	-	-	-	-	-	/	910	/	960	660
7G3-S	-	-	-	-	-	-	/	980	/	1170	601

NS = north-south antenna.
EW = east-west antenna.
B = both antennas.
- = site not established.
/ = data not taken.

TABLE G-4. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Slime Mold Studies

Site No., Meas. Pt.	1982		1983		1984		1985			1986	1987
	NS	EW	NS	EW	NS	EW	NS	EW	B(-75)	B(-75)	B(-75)
7A2-C	-	-	-	-	0.045, 0.051	44	/	44	44	40	42
7A2-N	-	-	-	-	-	-	/	/	/	42	45
7A2-S	-	-	-	-	-	-	/	/	/	39	41
7C1-C	0.012	0.014	0.012	0.013	0.011	0.013	/	/	0.016	0.016	0.017
7C1-N	-	-	-	-	-	-	/	/	/	0.016	0.016
7C1-S	-	-	-	-	-	-	/	/	/	0.016	0.017
7G3-C	-	-	0.060	5.2	0.078	5.6	/	3.2	3.1	3.9	3.03
7G3-N	-	-	-	-	-	-	/	/	/	4.0	3.2
7G3-S	-	-	-	-	-	-	/	/	/	3.9	3.1

NS = north-south antenna.

EW = east-west antenna.

B = both antennas.

- = site not established.

/ = data not taken.

given for each of the three currently active sites. Where available, 76 Hz data from previous years are presented for reference.

A data logger was installed at each of the slime mold study sites during the week of 6 July 1987. These instruments measure and record the drive voltage and current for each culture chamber on an hourly basis. Monitoring of the culture chambers continued until the end of the field season in mid-October. Results of the measurements have been provided to the principal investigator of the slime mold studies, but are not included in this report because of their length.

Comparison of the data in the tables indicates that there were no significant changes in the 76 Hz EM field intensities at either the antenna or control site in 1987. At the ground site, however, the EM fields were reduced from the 1986 measurements and were at approximately the levels recorded in 1985. Previous changes in the ground site fields were attributed to rebalancing of the west ground terminal segment currents. However, no rebalancing of currents was made on this segment of the west ground between the 1986 and 1987 measurements. It is therefore likely that the observed EM field variations are the result of changes in soil moisture and conductivity and their effect on ground current distribution in the ROW adjacent to the study site.

Measurements of 60 Hz ambient EM fields could not be conducted at the WTF in 1987 as in previous years, because of its full-time modulated signal operation. 60 Hz EM field data from 1984 and early 1985 were given in the 1985 annual measurement report.*

*ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1985. IIT Research Institute Technical Report E06549-24, September 1986, 48 pp. plus appendixes.

APPENDIX H
WETLANDS STUDIES

WETLANDS STUDIES

On 18-21 August 1987, IITRI field crews made ELF electromagnetic (EM) field measurements at 66 measurement points at a total of three antenna, two ground, three control, and three intermediate sites for the wetlands studies. The study sites and measurement points within the study sites were unchanged from 1986.

The positions of the 11 sites relative to the WTF are shown on the composite map in Figure H-1. The site numbers listed on the map are those used by IITRI. Table H-1 provides a cross-reference of IITRI site numbers, investigator site names, and township, range, and section numbers for the sites.

The wetlands studies examine the competitive ability of three types of wetlands plants (herbs, shrubs, and trees) by studying the organismal characteristics of leaf diffusion and cation transport. The functional operation of the decomposer community is also assessed by studying the decomposition rate of standardized cellulose material. The electric and magnetic fields in the earth are considered important EM factors influencing wetlands biota and processes. The electric and magnetic fields in the air can influence any object extending above the surface; for this reason, these fields are also considered important factors influencing wetlands biota and processes. The specific design of the study plots (long and narrow) and their orientation (parallel to the antenna) diminish the need for field gradient measurements across their width (4 m). However, data were taken at measurement points along the length (60 m) of the plots.

Tables H-2, H-3, and H-4 present a summary of the 76 Hz transverse electric field intensities, longitudinal electric field intensities, and magnetic flux densities, respectively, as measured at the study sites. Where available, 76 Hz data from previous years are presented for reference.

Longitudinal electric field and magnetic flux measurements were taken at each site by straddling the water sampling well with the orthogonal legs of the longitudinal electric field probe. The transverse electric field was measured in a clearing as close as possible to the water sampling well.

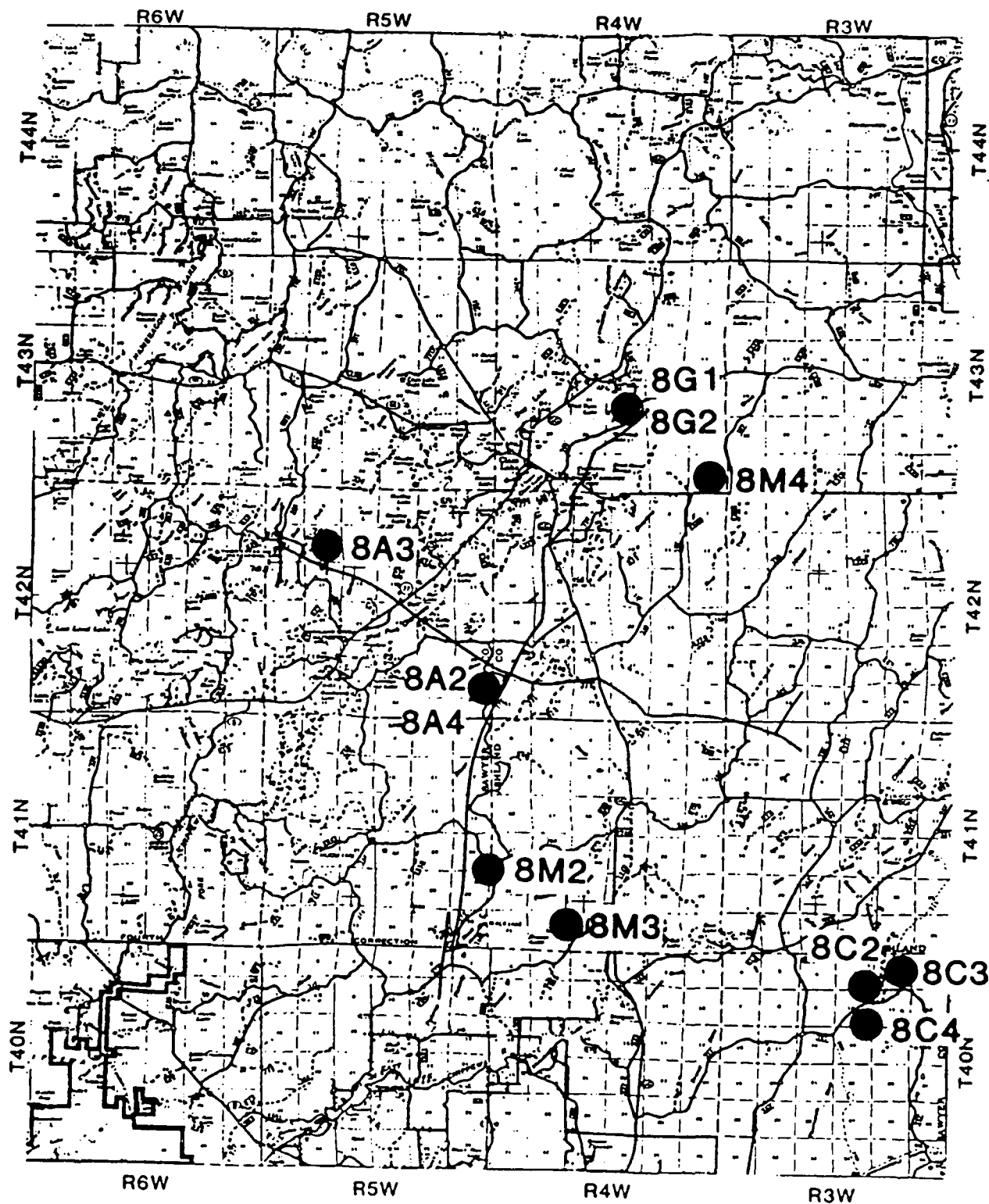


FIGURE H-1. POSITIONS OF WETLAND STUDY SITES RELATIVE TO WISCONSIN TRANSMITTING FACILITY ANTENNA ELEMENTS.

TABLE H-1. SITE NO. CROSS-REFERENCE
Wetlands Studies

IITRI Site No.	Investigator's Site Name	Location		
		Township	: Range	: Section(s)
8A2	UW Site 22 Antenna	T42N	: R4W	: 31
8A3	UW Site 40 Antenna	T42N	: R5W	: 8
8A4	UW Site 21.2 Antenna	T41N	: R5W	: 1
8G1	UW Site 10.1 Ground	T43N	: R4W	: 22
8G2	UW Site 10.2 Ground	T43N	: R4W	: 22
8C2	UW Site 20 Control	T40N	: R3W	: 10
8C3	UW Site 41 Control	T40N	: R3W	: 2
8C4	UW Site 50 Control	T40N	: R3W	: 10
8M2	UW Site 2 Intermediate	T41N	: R4W	: 19
8M3	UW Site 7 Intermediate	T41N	: R4W	: 33
8M4	UW Site 11 Intermediate	T43N	: R4W	: 36

TABLE H-2. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Wetlands Studies (page 1 of 3)

Site No., Meas. Pt.	1983		1984		1985	1986	1987
	NS	EW	NS	EW	B(-75)	B(-75)	B(-75)
8A2-A	0.174	0.015	--	--	--	--	--
8A2-B	0.127	0.023	--	--	--	--	--
8A2-C	0.104	0.011	--	--	--	--	--
8A2-1	-	-	0.155	0.051	/	0.141	0.072
8A2-2	-	-	0.142	0.047	/	0.104	0.054
8A2-3	-	-	0.124	0.045	/	0.114	0.053
8A2-4	-	-	0.29	0.088	/	0.177	0.086
8A2-5	-	-	0.55	0.116	/	0.35	0.183
8A2-6	-	-	0.31	0.066	/	0.175	0.116
8A3-A	0.009	0.116	--	--	--	--	--
8A3-B	0.010	0.139	--	--	--	--	--
8A3-C	0.011	0.163	--	--	--	--	--
8A3-1	-	-	0.008	0.144	/	0.130	0.126
8A3-2	-	-	0.008	0.186	/	0.151	0.132
8A3-3	-	-	0.010	0.161	/	0.115	0.121
8A3-4	-	-	0.006	0.160	/	0.137	0.120
8A3-5	-	-	0.007	0.185	/	0.125	0.111
8A3-6	-	-	0.008	0.137	/	0.144	0.122
8A3-7	-	-	0.007	0.153	--	--	--
8A4-1	-	-	0.161	0.007	/	0.066	0.196
8A4-2	-	-	0.155	0.006	/	0.087	0.169
8A4-3	-	-	0.145	0.007	/	0.106	0.121
8A4-4	-	-	0.118	0.005	/	0.095	0.116
8A4-5	-	-	0.089	0.005	/	0.079	0.095
8A4-6	-	-	0.096	0.005	/	0.098	0.083
8C2-A	<0.001	<0.001	--	--	--	--	--
8C2-B	<0.001	<0.001	--	--	--	--	--
8C2-1	-	-	-	-	-	-	-
8C2-2	-	-	-	-	-	-	-
8C2-3	-	-	-	-	-	-	-
8C2-4	-	-	-	-	-	-	-
8C2-5	-	-	-	-	-	-	-
8C2-6	-	-	-	-	-	-	-
8C3-A	<0.001	<0.001	--	--	--	--	--
8C3-B	<0.001	<0.001	--	--	--	--	--
8C3-C	<0.001	<0.001	--	--	--	--	--

TABLE H-2. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Wetlands Studies (page 2 of 3)

Site No., Meas. Pt.	1983		1984		1985	1986	1987
	NS	EW	NS	EW	B(-75)	B(-75)	B(-75)
8C3-1	-	-	-	-	-	-	-
8C3-2	-	-	-	-	-	-	-
8C3-3	-	-	-	-	-	-	-
8C3-4	-	-	-	-	-	-	-
8C3-5	-	-	-	-	-	-	-
8C3-6	-	-	-	-	-	-	-
8C4-A	-	-	<0.001	<0.001	--	--	--
8C4-B	-	-	/	/	--	--	--
8C4-C	-	-	/	/	--	--	--
8C4-1	-	-	-	-	-	-	-
8C4-2	-	-	-	-	-	-	-
8C4-3	-	-	-	-	-	-	-
8C4-4	-	-	-	-	-	-	-
8C4-5	-	-	-	-	-	-	-
8C4-6	-	-	-	-	-	-	-
8G1-A	0.59	0.024	--	--	--	--	--
8G1-B	0.49	0.019	--	--	--	--	--
8G1-C	0.45	0.017	--	--	--	--	--
8G1-1	-	-	0.73	0.010	0.25	0.185	0.147
8G1-2	-	-	0.59	0.006	0.26	0.22	0.184
8G1-3	-	-	0.59	0.006	0.29	0.193	0.172
8G1-4	-	-	0.80	0.008	0.32	0.23	0.154
8G1-5	-	-	0.68	0.006	0.29	0.166	0.126
8G1-6	-	-	0.49	0.004	0.30	0.111	0.124
8G2-A	0.29	0.013	--	--	--	--	--
8G2-B	0.32	0.015	--	--	--	--	--
8G2-C	0.26	0.010	--	--	--	--	--
8G2-1	-	-	/	/	0.25	0.150	0.111
8G2-2	-	-	/	/	0.181	0.117	0.095
8G2-3	-	-	/	/	0.20	0.129	0.113
8G2-4	-	-	0.32	0.003	0.24	0.125	0.109
8G2-5	-	-	0.39	0.005	0.21	0.107	0.093
8G2-6	-	-	0.40	0.004	0.185	0.125	0.111
8M2-A	0.058	0.005	--	--	--	--	--
8M2-B	0.069	0.006	--	--	--	--	--
8M2-C	0.077	0.008	--	--	--	--	--

TABLE H-2. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Wetlands Studies (page 3 of 3)

Site No., Meas. Pt.	1983		1984		1985	1986	1987
	NS	EW	NS	EW	B(-75)	B(-75)	B(-75)
8M2-1	-	-	0.054	0.005	0.062	0.047	0.043
8M2-2	-	-	0.059	0.005	/	0.054	0.060
8M2-3	-	-	0.056	0.006	0.066	0.050	0.048
8M2-4	-	-	0.062	0.005	/	0.051	0.052
8M2-5	-	-	0.067	0.006	/	0.057	0.050
8M2-6	-	-	0.074	0.006	0.065	0.058	0.058
8M3-A	0.013	0.005	--	--	--	--	--
8M3-B	0.013	0.007	--	--	--	--	--
8M3-C	0.013	0.005	--	--	--	--	--
8M3-1	-	-	0.016	0.008	0.010	0.006	0.007
8M3-2	-	-	0.018	0.008	/	0.010	0.007
8M3-3	-	-	0.015	0.006	0.009	0.010	0.007
8M3-4	-	-	0.018	0.006	/	0.012	0.009
8M3-5	-	-	0.015	0.005	/	0.010	0.008
8M3-6	-	-	0.013	0.007	0.011	0.009	0.008
8M4-A	/	/	--	--	--	--	--
8M4-B	/	/	--	--	--	--	--
8M4-C	/	/	--	--	--	--	--
8M4-1	-	-	0.010	0.003	/	0.012	0.012
8M4-2	-	-	0.008	0.004	/	0.012	0.012
8M4-3	-	-	0.008	0.004	/	0.008	0.009
8M4-4	-	-	0.007	0.005	/	0.007	0.011
8M4-5	-	-	0.010	0.004	/	0.007	0.011
8M4-6	-	-	0.010	0.003	/	0.008	0.012

NS = north-south antenna.

EW = east-west antenna.

B = both antennas.

- = site not established.

-- = site dropped.

/ = data not taken.

** = 8G1 and 8G2 data for north-south antenna only.

TABLE H-3. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Wetlands Studies (page 1 of 3)

Site No., Meas. Pt.	1983		1984		1985	1986	1987
	NS	EW	NS	EW	B(-75)	B(-75)	B(-75)
8A2-A	138	11.4	--	--	--	--	--
8A2-B	79	13.5	--	--	--	--	--
8A2-C	45	4.1	--	--	--	--	--
8A2-1	-	-	116	36	77	118	64
8A2-2	-	-	98	32	62	100	54
8A2-3	-	-	96	42	60	106	50
8A2-4	-	-	176,177	55,57	111	182	107
8A2-5	-	-	360,370	90,91	264	340	270
8A2-6	-	-	151,153	36	123	147	144
8A3-A	9.8	134	--	--	--	--	--
8A3-B	9.3	142	--	--	--	--	--
8A3-C	9.5	151	--	--	--	--	--
8A3-1	-	-	8.1	137	137	131	136
8A3-2	-	-	7.7	151	144	138	148
8A3-3	-	-	7.4	145	140	138	145
8A3-4	-	-	7.5	126	118	117	119
8A3-5	-	-	7.6	152	137	136	137
8A3-6	-	-	7.8	157	146	146	148
8A3-7	-	-	7.8	131	--	--	--
8A4-1	-	-	149	5.6	171	183	172
8A4-2	-	-	140	5.0	156	155	156
8A4-3	-	-	121	5.4	121	124	115
8A4-4	-	-	117	5.6	104	102	102
8A4-5	-	-	94	4.9	89	91	76
8A4-6	-	-	88	4.9	77	73	74
8C2-A	0.62	0.59	--	--	--	--	--
8C2-B	0.65	0.60	--	--	--	--	--
8C2-1	-	-	/	/	/	0.98	1.02
8C2-2	-	-	/	/	/	1.07	1.09
8C2-3	-	-	/	/	1.07	1.09	1.13
8C2-4	-	-	0.80	0.76	/	1.24	1.23
8C2-5	-	-	0.74	0.70	/	1.04	1.06
8C2-6	-	-	0.62	0.60	/	0.89	0.91
8C3-A	0.81	0.86	--	--	--	--	--
8C3-B	0.77	0.83	--	--	--	--	--
8C3-C	0.85	0.91	--	--	--	--	--

TABLE H-3. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Wetlands Studies (page 2 of 3)

Site No., Meas. Pt.	1983		1984		1985	1986	1987
	NS	EW	NS	EW	B(-75)	B(-75)	B(-75)
8C3-1	-	-	0.81	0.88	/	1.24	1.30
8C3-2	-	-	0.82	0.97	/	1.26	1.33
8C3-3	-	-	0.84	0.90	1.32	1.30	1.28
8C3-4	-	-	0.85	0.92	/	1.32	1.36
8C3-5	-	-	0.84	0.91	/	1.37	1.35
8C3-6	-	-	0.79	0.85	/	1.22	1.29
8C4-A	-	-	0.93	0.69	--	--	--
8C4-B	-	-	0.72	0.73	--	--	--
8C4-C	-	-	0.72	0.70	--	--	--
8C4-1	-	-	0.83	0.72	/	1.20	1.15
8C4-2	-	-	0.84	0.72	/	1.19	1.17
8C4-3	-	-	0.74	0.73	/	1.13	1.16
8C4-4	-	-	0.85	0.72	1.15	1.15	1.17
8C4-5	-	-	0.82	0.69	/	1.10	1.08
8C4-6	-	-	0.85	0.72	/	1.10	1.13
8G1-A	430	15.9	--	--	--	--	--
8G1-B	490	18.1	--	--	--	--	--
8G1-C	410	14.8	--	--	--	--	--
8G1-1	-	-	420	4.0	195	184	184
8G1-2	-	-	470	4.6	220	200	196
8G1-3	-	-	460	4.5	230	230	230
8G1-4	-	-	470	4.5	230	200	176
8G1-5	-	-	430	4.1	220	185	160
8G1-6	-	-	460	4.4	240	176	156
8G2-A	280	10.9	--	--	--	--	--
8G2-B	310	12.1	--	--	--	--	--
8G2-C	230	9.3	--	--	--	--	--
8G2-1	-	-	280	3.3	184	145	127
8G2-2	-	-	270	3.0	162	134	120
8G2-3	-	-	280	3.3	158	130	130
8G2-4	-	-	260	3.1	143	125	124
8G2-5	-	-	280	3.4	146	121	118
8G2-6	-	-	300	3.7	155	132	142
8M2-A	49	4.8	--	--	--	--	--
8M2-B	55	5.3	--	--	--	--	--
8M2-C	75	6.4	--	--	--	--	--

TABLE H-3. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Wetlands Studies (page 3 of 3)

Site No., Meas. Pt.	1983		1984		1985	1986	1987
	NS	EW	NS	EW	B(-75)	B(-75)	B(-75)
8M2-1	-	-	52	4.2	51	49	50
8M2-2	-	-	60	4.6	/	56	54
8M2-3	-	-	58	4.7	57	52	54
8M2-4	-	-	57	4.8	/	54	54
8M2-5	-	-	66	5.1	/	59	58
8M2-6	-	-	70	5.3	64	61	65
8M3-A	9.5	4.0	--	--	--	--	--
8M3-B	13.3	6.0	--	--	--	--	--
8M3-C	11.6	3.6	--	--	--	--	--
8M3-1	-	-	11.7	5.1	7.7	7.7	7.4
8M3-2	-	-	12.0	4.9	/	7.4	7.3
8M3-3	-	-	13.5	5.4	9.2	8.7	8.5
8M3-4	-	-	15.1	4.7	/	12.7	14.7
8M3-5	-	-	12.7	4.1	/	10.4	10.6
8M3-6	-	-	13.4	4.5	10	10.1	10.5
8M4-A	6.6	3.1	--	--	--	--	--
8M4-B	2.8	2.8	--	--	--	--	--
8M4-C	3.1	1.02	--	--	--	--	--
8M4-1	-	-	6.9	3.1	5.5	5.2	5.5
8M4-2	-	-	7.2	3.2	/	5.8	5.7
8M4-3	-	-	7.2	3.0	5.5	5.6	5.5
8M4-4	-	-	7.2	2.9	/	5.5	5.5
8M4-5	-	-	7.0	2.9	/	5.7	5.5
8M4-6	-	-	7.0	3.0	5.5	5.6	5.7

NS = north-south antenna.

EW = east-west antenna.

B = both antennas.

- = site not established.

-- = site dropped.

/ = data not taken.

** = 8G1 and 8G2 data for north-south antenna only.

TABLE H-4. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Wetlands Studies (page 1 of 3)

Site No., Meas. Pt.	1983		1984		1985	1986	1987
	NS	EW	NS	EW	B(-75)	B(-75)	B(-75)
8A2-A	7.5	0.45	--	--	--	--	--
8A2-B	7.1	0.45	--	--	--	--	--
8A2-C	7.7	0.45	--	--	--	--	--
8A2-1	-	-	7.2	0.23	6.9	7.1	6.4
8A2-2	-	-	7.1	0.23	6.5	6.9	6.2
8A2-3	-	-	7.1	0.23	6.5	6.9	6.1
8A2-4	-	-	7.2	0.23	6.7	6.9	7.0
8A2-5	-	-	7.2	0.23	6.5	6.9	7.0
8A2-6	-	-	7.2	0.23	6.5	6.9	6.9
8A3-A	0.055	22	--	--	--	--	--
8A3-B	0.055	21	--	--	--	--	--
8A3-C	0.054	23	--	--	--	--	--
8A3-1	-	-	0.114	19.1	17.5	18.3	19.2
8A3-2	-	-	0.115	19.5	17.5	18.0	18.7
8A3-3	-	-	0.115	19.4	18.6	18.0	19.0
8A3-4	-	-	0.116	20	17.7	18.3	19.2
8A3-5	-	-	0.116	20	18.5	19.7	19.8
8A3-6	-	-	0.113	18.8	16.5	16.8	17.6
8A3-7	-	-	0.126	23	--	--	--
8A4-1	-	-	8.9	0.154	8.1	8.6	8.6
8A4-2	-	-	8.4	0.167	7.9	8.2	8.3
8A4-3	-	-	8.0	0.158	7.7	8.0	8.3
8A4-4	-	-	8.0	0.158	7.5	7.7	7.9
8A4-5	-	-	7.8	0.159	7.5	7.5	7.3
8A4-6	-	-	8.0	0.161	7.4	7.5	7.9
8C2-A	0.013	0.011	--	--	--	--	--
8C2-B	0.012	0.011	--	--	--	--	--
8C2-1	-	-	/	/	/	0.017	0.017
8C2-2	-	-	/	/	/	0.017	0.017
8C2-3	-	-	/	/	0.016	0.017	0.017
8C2-4	-	-	0.013	0.012	/	0.017	0.017
8C2-5	-	-	0.013	0.012	/	0.017	0.017
8C2-6	-	-	0.013	0.012	/	0.017	0.017
8C3-A	0.013	0.012	--	--	--	--	--
8C3-B	0.013	0.012	--	--	--	--	--
8C3-C	0.013	0.012	--	--	--	--	--

TABLE H-4. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Wetlands Studies (page 2 of 3)

Site No., Meas. Pt.	1983		1984		1985	1986	1987
	NS	EW	NS	EW	B(-75)	B(-75)	B(-75)
8C3-1	-	-	0.011	0.011	/	0.015	0.016
8C3-2	-	-	0.011	0.011	/	0.015	0.016
8C3-3	-	-	0.012	0.011	0.015	0.015	0.016
8C3-4	-	-	0.012	0.011	/	0.016	0.015
8C3-5	-	-	0.011	0.010	/	0.016	0.016
8C3-6	-	-	0.012	0.011	/	0.015	0.015
8C4-A	-	-	0.012	0.011	--	--	--
8C4-B	-	-	0.013	0.011	--	--	--
8C4-C	-	-	0.013	0.011	--	--	--
8C4-1	-	-	0.012	0.010	/	0.015	0.015
8C4-2	-	-	0.012	0.010	/	0.015	0.015
8C4-3	-	-	0.012	0.010	/	0.015	0.016
8C4-4	-	-	0.012	0.010	0.015	0.015	0.015
8C4-5	-	-	0.011	0.010	/	0.015	0.015
8C4-6	-	-	0.011	0.010	/	0.015	0.015
8G1-A	2.3	0.083	--	--	--	--	--
8G1-B	2.3	0.083	--	--	--	--	--
8G1-C	2.2	0.081	--	--	--	--	--
8G1-1	-	-	2.1	0.036	1.44	0.74	0.76
8G1-2	-	-	2.2	0.036	1.43	0.76	0.79
8G1-3	-	-	2.2	0.037	1.39	0.74	0.76
8G1-4	-	-	2.1	0.036	1.39	0.74	0.70
8G1-5	-	-	2.1	0.036	1.37	0.74	0.70
8G1-6	-	-	2.0	0.036	1.26	0.66	0.64
8G2-A	0.63	0.038	--	--	--	--	--
8G2-B	0.68	0.054	--	--	--	--	--
8G2-C	0.66	0.039	--	--	--	--	--
8G2-1	-	-	0.64	0.031	0.33	0.22	0.20
8G2-2	-	-	0.64	0.032	0.32	0.22	0.20
8G2-3	-	-	0.67	0.032	0.33	0.23	0.23
8G2-4	-	-	0.68	0.032	0.33	0.23	0.23
8G2-5	-	-	0.69	0.030	0.34	0.22	0.23
8G2-6	-	-	0.72	0.032	0.32	0.22	0.22
8M2-A	0.48	0.074	--	--	--	--	--
8M2-B	0.49	0.077	--	--	--	--	--
8M2-C	0.48	0.076	--	--	--	--	--

TABLE H-4. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Wetlands Studies (page 3 of 3)

Site No., Meas. Pt.	1983		1984		1985	1986	1987
	NS	EW	NS	EW	B(-75)	B(-75)	B(-75)
8M2-1	-	-	0.48	0.072	0.50	0.49	0.51
8M2-2	-	-	0.48	0.071	/	0.51	0.52
8M2-3	-	-	0.49	0.071	0.51	0.51	0.51
8M2-4	-	-	0.48	0.072	/	0.51	0.52
8M2-5	-	-	0.49	0.073	/	0.51	0.55
8M2-6	-	-	0.49	0.073	0.51	0.50	0.52
8M3-A	0.080	0.036	--	--	--	--	--
8M3-B	0.080	0.037	--	--	--	--	--
8M3-C	0.078	0.034	--	--	--	--	--
8M3-1	-	-	0.083	0.036	0.098	0.091	0.099
8M3-2	-	-	0.085	0.036	/	0.094	0.097
8M3-3	-	-	0.084	0.036	0.097	0.095	0.097
8M3-4	-	-	0.084	0.038	/	0.093	0.082
8M3-5	-	-	0.084	0.036	/	0.094	0.099
8M3-6	-	-	0.085	0.036	0.096	0.094	0.097
8M4-A	0.101	0.058	--	--	--	--	--
8M4-B	0.100	0.047	--	--	--	--	--
8M4-C	0.088	0.049	--	--	--	--	--
8M4-1	-	-	0.093	0.055	0.082	0.082	0.087
8M4-2	-	-	0.092	0.055	/	0.083	0.085
8M4-3	-	-	0.092	0.054	0.083	0.084	0.085
8M4-4	-	-	0.091	0.054	/	0.081	0.085
8M4-5	-	-	0.091	0.054	/	0.082	0.082
8M4-6	-	-	0.091	0.054	0.082	0.083	0.086

NS = north-south antenna.

EW = east-west antenna.

B = both antennas.

- = site not established.

-- = site dropped.

/ = data not taken.

** = 8G1 and 8G2 data for north-south antenna only.

Comparison of the data in the tables indicates that there were no significant changes in the 76 Hz EM field intensities at the Wisconsin transects in 1987, with the exception of the longitudinal electric fields at site 8A2. The electric fields at this site were again reduced from the 1984 and 1986 values to approximately the 1985 levels, as indicated in Table H-3. This site has a long history of electric field fluctuations for which the only explanation would appear to be seasonal or annual changes in the overall soil conductivity. The slight magnetic field changes noted at site 8A2 are within the range of variation normally associated with the basic repeatability and accuracy of the magnetic field measurements. The ground test sites, 8G1 and 8G2, which experienced EM field changes from 1985 to 1986 due to physical alterations in the WTF north ground, had 1987 EM field levels consistent with those in 1986.

The transverse electric fields in the air were again measured at each site in 1987 when possible. These fields at all sites are highly influenced by nearby vegetation, which can cause significant localized field shielding or enhancement. Therefore, every attempt was made to locate the electric field probe in nearby areas that are generally clear of trees or large shrubs, in order to obtain a relatively unperturbed measurement of the field. These areas were typically within a few meters of the wells. At all wetlands sites, the electric field in the air is generated by the electric field in the earth, and is predominantly horizontal; the overhead antenna wire is too far away to produce a vertical field. The close relationship between the electric fields in the earth and air is easily seen in the data tables for the antenna, ground, and intermediate sites. At the control sites, the intensities of the electric field in the air were estimated to be less than 0.001 V/m, the probe's lower limit of sensitivity. This is based on previous measurement attempts and the measured values of the electric fields in the earth.

As in 1985 and 1986, measurements of 60 Hz ambient EM fields could not be conducted at the WTF, because of its full-time modulated signal operation. 60 Hz EM field data from 1984 and early 1985 were given in the 1985 annual measurement report.*

*ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1985. IIT Research Institute Technical Report E06549-24, September 1986, 48 pp. plus appendixes.

APPENDIX I
BIRD SPECIES AND COMMUNITIES STUDIES

BIRD SPECIES AND COMMUNITIES STUDIES

On 18-22 August 1987, IITRI field crews made ELF electromagnetic (EM) field measurements at 22 measurement points at a total of five test and five control transects for the bird species and communities studies in Wisconsin. All transects measured in 1987 were established in previous years. One measurement point on the Brunet River transect (10C10-2) could not be found due to logging activity and was relocated to 10C10-3.

On 23-25 and 30 September 1987, IITRI field crews made ELF EM field measurements at 24 measurement points at a total of five test and five control transects for the bird species and communities studies in Michigan. The study transects and measurement points within the study transects were unchanged from 1986.

The positions of the 10 Wisconsin transects and 10 Michigan transects relative to the WTF and MTF, respectively, are shown on the composite maps in Figures I-1 and I-2. The transect numbers listed on the map are those used by IITRI. Table I-1 provides a cross-reference of IITRI transect numbers, investigator transect names, and township, range, and section numbers for the transects in both Wisconsin and Michigan.

The bird species and communities studies monitor migrating bird population using a census technique that involves variable-width transects. The study involves monitoring the total population of migrating birds in an area both as a whole and as individual species. The electric and magnetic fields in the air are considered the most important EM factors influencing migrating birds; however, the electric field in the earth may also have an influence.

Wisconsin Measurements

EM field measurements for 1987 and previous years are found in Tables I-2, I-3, and I-4, which present 76 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. In 1986 and 1987, all measurements were made during simultaneous phased operation of both antenna elements. In years prior to 1986, control of antenna conditions was possible, and EM field measurements were made under individual antenna operation modes. These data are included in Tables I-2,

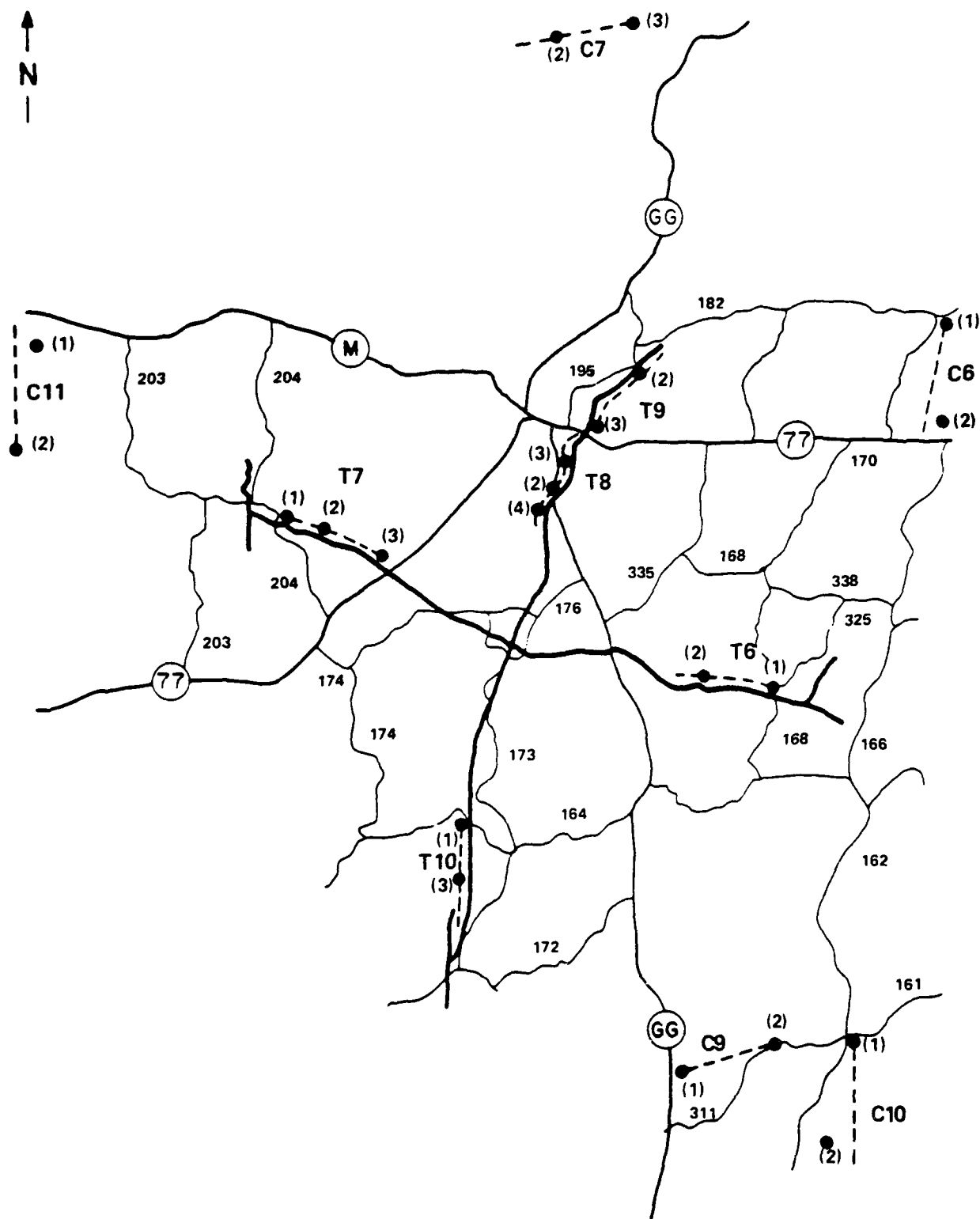


FIGURE I-1. POSITIONS OF BIRD SPECIES AND COMMUNITY STUDIES TRANSECTS
RELATIVE TO WISCONSIN TRANSMITTING FACILITY ANTENNA ELEMENTS.

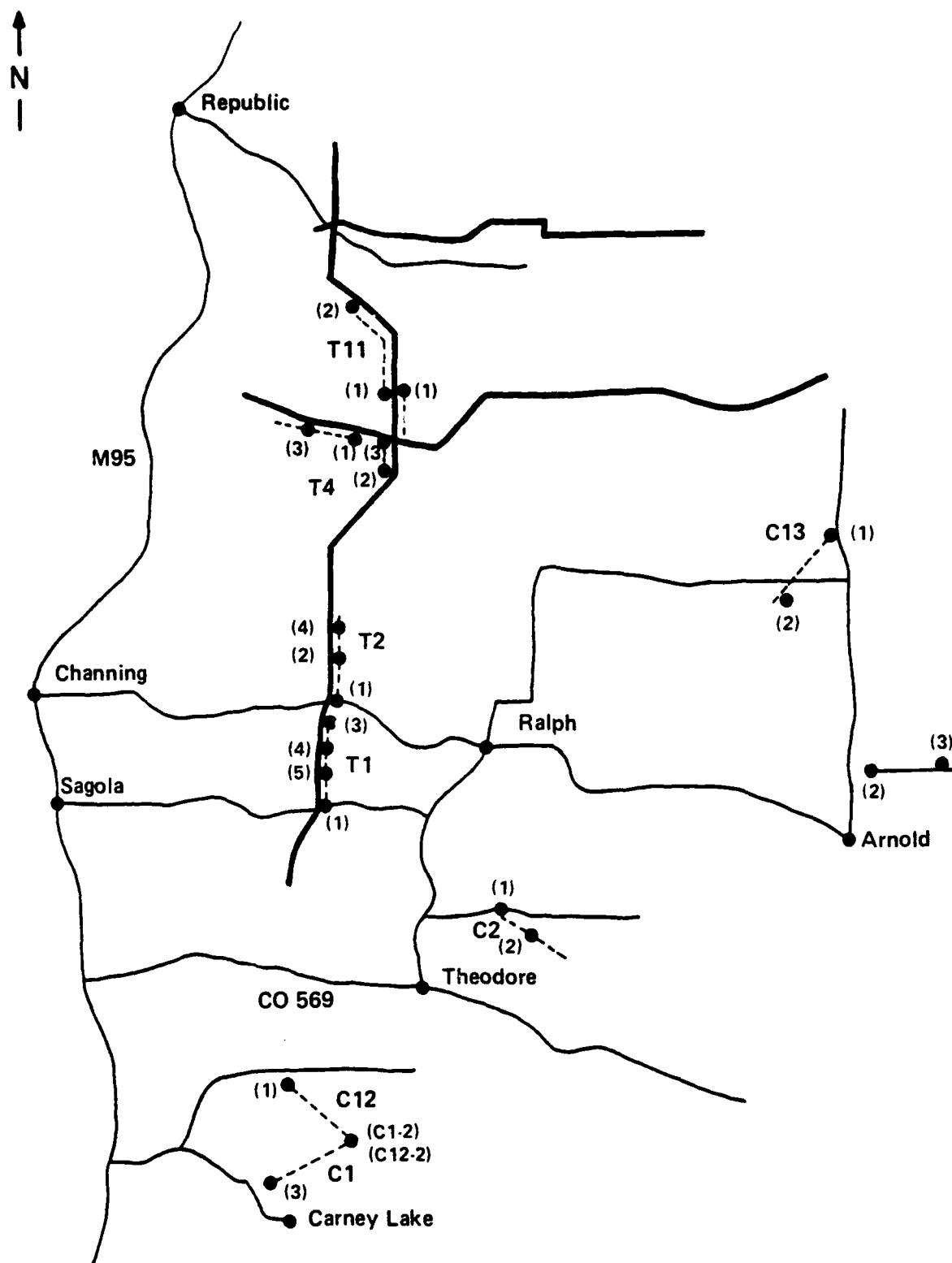


FIGURE I-2. POSITIONS OF BIRD SPECIES AND COMMUNITY STUDIES TRANSECTS
RELATIVE TO MICHIGAN TRANSMITTING FACILITY ANTENNA ELEMENTS.

TABLE I-1. TRANSECT NO. CROSS-REFERENCE
Bird Species and Communities Studies

IITRI Transect No.	Investigator's Transect Name	Location		
		Township	: Range	: Section(s)
Wisconsin				
10C6	Spillerberg Lake	T43N	: R3W	: 23, 26, 35
10C7	Mineral Lake	T44N	: R4W	: 15, 16, 17, 18
10C9	Blaisdell Lake	T40N	: R3W	: 18
		T40N	: R4W	: 13, 14, 22, 23
10C10	Brunet River	T40N	: R3W	: 16, 21, 28
10C11	Rock Lake	T42N	: R6W	: 6
		T43N	: R6W	: 19, 30, 31
10T6	Moose River	T42N	: R3W	: 31
		T42N	: R4W	: 35, 36
10T7	Christy Lake	T42N	: R5W	: 7, 8, 15, 16, 17
10T8	Little Clam Lake	T42N	: R4W	: 5, 8, 17
10T9	Woodtick Lake	T43N	: R4W	: 22, 23, 27, 28, 33
10T10	Black Lake	T41N	: R5W	: 24, 25, 36
Michigan				
10C1	Carney Lake	T41N	: R29W	: 33, 34, 35, 36
10C2	Skunk Creek	T42N	: R27W	: 19, 30
		T42N	: R28W	: 14, 23, 24
10C5	Arnold	T43N	: R25W	: 31, 32, 33, 34
10C12	Lost Lake	T41N	: R29W	: 21, 26, 27, 28, 35
10C13	Bob's Creek	T44N	: R26W	: 13, 23, 24, 26
10T1	Leeman's Road	T43N	: R29W	: 14, 23, 26, 35
10T2	Turner Road	T43N	: R29W	: 1, 12
		T44N	: R29W	: 36
10T3	Flat Rock Creek	T45N	: R28W	: 19, 30, 31
10T4	Schwartz Creek	T45N	: R28W	: 31
		T45N	: R29W	: 26, 27, 35, 36
10T11	Heart Lake	T45N	: R28W	: 7, 18, 19
		T45N	: R29W	: 1, 12

I-3, and I-4. There were no significant differences in any of the 76 Hz field measurements in Wisconsin between 1986 and 1987.

Measurements of 60 Hz ambient EM fields could not be conducted at the WTF in 1987 as a result of its full-time operating status and modulated signal. Previous 60 Hz measurements are given in the 1985 report.*

Michigan Measurements

EM measurements for Michigan in 1987 and previous years are found in Tables I-5 through I-13. Tables I-5, I-6, and I-7 present 60 Hz data for the transverse electric field, longitudinal electric field, and magnetic flux density, respectively. Tables I-8, I-9, and I-10 present 76 Hz data for these three fields at 1986 and 1987 MTF operating currents. Tables I-11, I-12, and I-13 present 76 Hz data extrapolated to a full-power condition of 150 amperes.

*ELF Communications System Ecological Monitoring Program: Electromagnetic Field Measurements and Engineering Support--1985. IIT Research Institute Technical Report E06549-24, September 1986, 48 pp. plus appendixes.

TABLE I-2. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Bird Species and Community Studies
Wisconsin Transects

Site No., Meas. Pt.	1984		1985			1986	1987
	NS	EW	NS	EW	B(-75)	B(-75)	B(-75)
10C6-1	-	-	/	/	-	-	-
10C6-2	-	-	/	/	-	-	-
10C7-2	-	-	-	/	-	-	-
10C7-3	-	-	-	-	-	-	-
10C9-1	-	-	/	/	-	-	-
10C9-2	-	-	/	/	-	-	-
10C10-1	-	-	/	/	-	-	-
10C10-2	-	-	/	/	-	-	-
10C10-3	-	-	-	-	-	-	-
10C11-1	-	-	-	-	-	-	-
10C11-2	-	-	-	-	-	-	-
10T6-1	0.006	0.195	/	/	/	0.166	0.22
10T6-2	0.014	0.107	/	/	/	0.090	0.077
10T7-1	/	/	/	/	/	0.20	1.03
10T7-2	0.014	0.156	/	/	/	0.117	0.116
10T7-3	0.015	0.183	/	/	/	0.129	0.110
10T8-2	0.089	0.013	/	/	/	0.067	0.094
10T8-3	-	-	/	/	/	0.107	0.121
10T8-4	-	-	/	/	/	0.078	0.087
10T9-2	0.47	0.004	/	/	0.48	0.41	0.45
10T9-3	-	-	/	/	/	0.092	0.106
10T10-1	0.094	0.007	/	/	0.146	0.07	0.101
10T10-2	0.195	0.006	/	/	0.163	0.091	0.082

NS = north-south antenna.

EW = east-west antenna.

B = both antennas.

- = site measurement point not established.

-- = site measurement point dropped.

/ = data not taken.

- = measurement expected to be <0.002 V/m based on longitudinal electric field measurement.

TABLE I-3. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Bird Species and Community Studies
Wisconsin Transects

Site No., Meas. Pt.	1984		1985			1986	1987
	NS	EW	NS	EW	B(-75)	B(-75)	B(-75)
10C6-1	1.60	1.08	/	/	1.20	1.12	1.32
10C6-2	1.89	1.61	/	/	2.7	2.3	2.9
10C7-2	0.47	0.43	0.48	/	0.64	0.59	0.67
10C7-3	-	-	0.25,0.34	0.36	0.59	0.62	0.54
10C9-1	1.16	0.44	/	/	0.95	1.12	1.05
10C9-2	1.44	1.08	/	/	1.77	2.0	2.12
10C10-1	1.40	1.12	/	/	1.98	1.55	1.83
10C10-2	0.30	0.31	/	/	0.48	0.55	--
10C10-3	-	-	-	-	-	-	0.37
10C11-1	-	-	0.67	0.59	1.44	1.63	1.10
10C11-2	-	-	0.98	0.91	2.0	1.91	0.81
10T6-1	6.0	130	/	/	157	184	260
10T6-2	12.8	88	14.1	95	75	80	75
10T7-1	20	180	/	/	210	210	145
10T7-2	13.2	142	/	/	137	99	119
10T7-3	18.7	159	/	/	104	101	121
10T8-2	102	15.2	/	/	81	90	84
10T8-3	-	-	150	13.2	121	114	128
10T8-4	-	-	73,85	23,24	71	63	74
10T9-2	470	3.5	/	/	350	470	470
10T9-3	-	-	81	7.8	71	88	114
10T10-1	73	11.0	77	10.5	109	96	85
10T10-2	150	6.5	130	11.2	158	94	92

NS = north-south antenna.

EW = east-west antenna.

B = both antennas.

- = site measurement point not established.

-- = site measurement point dropped.

/ = data not taken.

TABLE I-4. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Bird Species and Community Studies
Wisconsin Transects

Site No., Meas. Pt.	1984		1985			1986	1987
	NS	EW	NS	EW	B(-75)	B(-75)	B(-75)
10C6-1	0.011	0.010	/	/	0.012	0.013	0.013
10C6-2	0.012	0.014	/	/	0.016	0.017	0.018
10C7-2	0.005	0.005	0.005	/	0.007	0.007	0.008
10C7-3	-	-	0.004, 0.005	0.005	0.007	0.006	0.007
10C9-1	0.030	0.017	/	/	0.035	0.037	0.037
10C9-2	0.022	0.015	/	/	0.027	0.027	0.027
10C10-1	0.017	0.014	/	/	0.023	0.023	0.025
10C10-2	0.008	0.007	/	/	0.011	0.011	--
10C10-3	-	-	-	-	-	-	0.012
10C11-1	-	-	/	/	0.011	0.011	0.011
10C11-2	-	-	0.009	<0.001	0.014	0.014	0.014
10T6-1	0.041	3.6	/	/	8.8	9.0	9.0
10T6-2	0.069	7.5	0.082	7.8	7.1	9.6	7.7
10T7-1	0.061	4.7	/	/	4.4	4.2	5.2
10T7-2	0.059	2.3	/	/	2.2	2.2	2.3
10T7-3	0.094	4.9	/	/	4.7	4.6	4.8
10T8-2	4.9	0.136	/	/	4.8	4.9	5.0
10T8-3	-	-	9.9	0.127	8.1	8.4	8.5
10T8-4	-	-	3.4, 6.6	0.192	3.4	3.4	3.6
10T9-2	1.58	0.033	/	/	2.4	2.2	2.2
10T9-3	-	-	4.1	0.072	3.4	3.7	3.9
10T10-1	4.5	0.063	4.5	0.066	5.7	4.3	4.5
10T10-2	4.9	0.050	3.7	0.042	4.7	3.9	3.9

NS = north-south antenna.

EW = east-west antenna.

B = both antennas.

- = site measurement point not established.

-- = site measurement point dropped.

/ = data not taken.

TABLE I-5. 60 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
Bird Species and Community Studies
Michigan Transects

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c
10C1-2	-	-	-	-	-
10C1-3	-	-	-	-	-
10C2-1	-	-	-	-	-
10C2-2	-	-	-	-	-
10C5-2	-	-	-	-	-
10C5-3	-	-	-	-	-
10C12-1	-	-	-	-	-
10C12-2	-	-	-	-	-
10C13-1	-	-	-	-	-
10C13-2	-	-	-	-	-
10T1-1	-	-	-	-	-
10T1-3	-	-	-	-	-
10T1-4	-	-	-	-	-
10T1-5	-	-	-	-	-
10T2-1	-	<0.001	-	-	-
10T2-2	-	-	-	-	-
10T2-4	-	-	-	-	-
10T3-1	-	-	-	-	-
10T3-2	-	-	-	-	-
10T3-3	-	-	-	-	-
10T4-1	-	-	-	-	-
10T4-3	-	-	-	-	-
10T11-1	-	-	-	-	-
10T11-2	-	-	-	-	0.011

^a = prior to antenna construction.

^b = antenna elements grounded at transmitter (condition 2).

^c = antenna elements connected to transmitter, transmitter off (condition 9).

- = site measurement point not established.

- = measurement expected to be <0.001 V/m based on the longitudinal electric field measurement.

TABLE I-6. 60 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Bird Species and Community Studies
Michigan Transects

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c
10C1-2	-	0.62	0.106,0.141	0.101	0.059
10C1-3	-	-	0.26,0.27	0.055	0.21
10C2-1	-	0.98	0.138	0.041	0.038
10C2-2	-	0.35	0.21	0.055	0.048
10C5-2	-	0.35	0.45	0.193	0.116
10C5-3	-	0.111	0.23	0.25	0.103
10C12-1	-	-	0.194,0.28	0.058	0.256
10C12-2	-	-	0.106,0.141	0.101	0.059
10C13-1	-	-	0.34,0.52	0.30	0.40
10C13-2	-	-	0.143,0.31	0.139	0.157
10T1-1	-	0.076	0.061	0.034	0.099
10T1-3	-	-	0.38	0.120	0.20
10T1-4	-	-	-	0.111	0.085
10T1-5	-	-	-	0.040	0.052
10T2-1	-	0.42	0.194	0.050	0.058
10T2-2	-	-	-	0.058	0.052
10T2-4	-	-	0.158	0.054	0.029
10T3-1	-	0.30	0.23	0.145	0.164
10T3-2	-	0.26	0.117	0.069	0.103
10T3-3	-	-	-	0.094	0.120
10T4-1	-	0.29	0.132	0.129	0.093
10T4-3	-	-	-	0.112	0.22
10T11-1	-	-	0.23	0.172	0.106
10T11-2	-	-	0.26,0.50	0.58	0.45

^a = prior to antenna construction.

^b = antenna elements grounded at transmitter (condition 2).

^c = antenna elements connected to transmitter, transmitter off (condition 9).

- = site measurement point not established.

TABLE I-7. 60 Hz MAGNETIC FLUX DENSITIES (mG)
Bird Species and Community Studies
Michigan Transects

Site No., Meas. Pt.	1983 ^a	1984 ^a	1985 ^a	1986 ^b	1987 ^c
10C1-2	-	0.001	0.001	<0.001	<0.001
10C1-3	-	-	0.001,0.003	<0.001	0.003
10C2-1	-	0.005	0.004	<0.001	<0.001
10C2-2	-	0.003	0.003	<0.001	0.001
10C5-2	-	0.008	0.009	0.006	0.005
10C5-3	-	0.001	0.002	0.002	0.001
10C12-1	-	-	0.001,0.003	0.002	0.003
10C12-2	-	-	0.001	<0.001	<0.001
10C13-1	-	-	0.007,0.010	0.007	0.005
10C13-2	-	-	0.001,<0.001	0.001	0.001
10T1-1	-	0.006	0.004	0.002	0.005
10T1-3	-	-	0.002	0.003	0.005
10T1-4	-	-	-	0.003	0.003
10T1-5	-	-	-	0.003	0.016
10T2-1	-	0.002	0.002	0.003	0.005
10T2-2	-	-	-	<0.001	0.002
10T2-4	-	-	0.001	0.002	0.001
10T3-1	-	0.001	0.001	0.006	0.003
10T3-2	-	0.001	<0.001	0.008	0.005
10T3-3	-	-	-	0.012	0.007
10T4-1	-	0.001	<0.001	0.002	0.002
10T4-3	-	-	-	0.001	0.003
10T11-1	-	-	<0.001	0.006	0.006
10T11-2	-	-	0.001,<0.001	0.008	0.005

^a = prior to antenna construction.

^b = antenna elements grounded at transmitter (condition 2).

^c = antenna elements connected to transmitter, transmitter off (condition 9).

- = site measurement point not established.

TABLE I-8. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
 Bird Species and Community Studies
 Measured (M) and Extrapolated (Ex) Data
 Michigan Transects

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M
10C1-2	-	-	-	--	-	-
10C1-3	-	-	-	--	-	-
10C2-1	-	-	-	--	-	-
10C2-2	-	-	-	--	-	-
10C5-2	-	-	-	--	-	-
10C5-3	-	-	-	--	-	-
10C12-1	-	-	-	--	-	-
10C12-2	-	-	-	--	-	-
10C13-1	-	-	-	--	-	-
10C13-2	-	-	-	--	-	-
10T1-1	-	-	-	--	0.005	-
10T1-3	0.002	-	-	--	0.007	-
10T1-4	-	-	-	--	0.004	-
10T1-5	-	-	-	--	0.003	-
10T2-1	0.002	-	-	--	0.006	-
10T2-2	0.002	-	-	--	0.007	-
10T2-4	0.002	-	-	--	0.007	-
10T3-1	0.004	-	-	--	0.005	0.003
10T3-2	0.004	-	0.001	0.002	0.006	0.003
10T3-3	0.005	-	0.017	0.028	0.005	0.009
10T4-1	0.002	-	0.003	0.005	0.003	0.006
10T4-3	-	-	0.003	0.005	0.001	0.008
10T11-1	-	-	-	--	0.004	0.002
10T11-2	-	-	-	--	0.038	0.009

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

- = measurement expected to be <0.001 based on the longitudinal electric field measurement.

-- = data cannot be extrapolated.

TABLE I-9. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Bird Species and Community Studies
Measured (M) and Extrapolated (Ex) Data
Michigan Transects

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M
10C1-2	0.004	0.003	0.004	0.007	0.015	0.012
10C1-3	0.013	0.004	0.002	0.003	0.049	0.011
10C2-1	0.017	0.002	0.007	0.012	0.073	0.021
10C2-2	0.011	0.003	0.007	0.012	0.037	0.020
10C5-2	0.001	0.003	0.007	0.012	0.014	0.023
10C5-3	0.005	0.003	0.009	0.015	0.017	0.027
10C12-1	0.028	0.010	0.011	0.018	0.068	0.028
10C12-2	0.004	0.003	0.004	0.007	0.015	0.012
10C13-1	0.024	0.027	0.104	0.173	0.057	0.24
10C13-2	0.024	0.023	0.098	0.163	0.089	0.29
10T1-1	0.85	0.028	0.008	0.013	2.8	0.015
10T1-3	2.2	0.068	0.077	0.128	7.1	0.147
10T1-4	0.96	0.030	0.031	0.052	4.1	0.087
10T1-5	0.65	0.020	0.006	0.010	2.3	0.015
10T2-1	1.42	0.043	0.077	0.128	5.3	0.25
10T2-2	1.69	0.056	0.107	0.178	7.0	0.34
10T2-4	0.59	0.056	0.158	0.26	5.0	0.49
10T3-1	0.82	0.23	0.60	1.00	4.9	2.1
10T3-2	1.24	0.133	1.05	1.75	5.4	2.7
10T3-3	1.36	-	3.6	6.0	4.8	7.5
10T4-1	0.88	0.137	1.58	2.6	2.4	4.8
10T4-3	0.46	0.139	1.92	3.2	1.30	8.1
10T11-1	0.67	0.27	0.59	0.98	3.9	1.97
10T11-2	1.38	0.93	0.44	0.73	7.3	2.9

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

- = measurement expected to be <0.001 based on the longitudinal electric field measurement.

TABLE I-10. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Bird Species and Community Studies
Measured (M) and Extrapolated (Ex) Data
Michigan Transects

Site No., Meas. Pt.	1986 Exposures; Antenna Element, Current (Amps)				1987 Exposures; Antenna Element, Current (Amps)	
	NS(4) M	NEW(6) M	SEW(6) M	SEW(10) Ex	NS(15) M	EW(15) M
10C1-2	<0.001	<0.001	<0.001	--	<0.001	<0.001
10C1-3	<0.001	<0.001	<0.001	--	<0.001	<0.001
10C2-1	<0.001	<0.001	<0.001	--	0.001	0.001
10C2-2	<0.001	<0.001	<0.001	--	0.001	<0.001
10C5-2	<0.001	<0.001	<0.001	--	<0.001	0.001
10C5-3	<0.001	<0.001	<0.001	--	<0.001	<0.001
10C12-1	<0.001	<0.001	<0.001	--	<0.001	<0.001
10C12-2	<0.001	<0.001	<0.001	--	<0.001	<0.001
10C13-1	<0.001	<0.001	<0.001	--	0.001	0.002
10C13-2	<0.001	<0.001	<0.001	--	<0.001	0.001
10T1-1	0.044	0.001	<0.001	--	0.179	0.001
10T1-3	0.047	0.001	0.007	0.012	0.176	0.001
10T1-4	0.026	0.001	0.001	0.002	0.103	0.002
10T1-5	0.034	0.001	0.001	0.002	0.49	0.002
10T2-1	0.066	0.002	0.001	0.002	0.25	0.001
10T2-2	0.043	0.001	0.001	0.002	0.165	0.002
10T2-4	0.026	0.001	0.001	0.002	0.097	0.002
10T3-1	0.029	0.003	0.007	0.012	0.188	0.015
10T3-2	0.081	0.002	0.013	0.022	0.29	0.031
10T3-3	0.116	0.40	0.58	0.97	0.196	0.89
10T4-1	0.025	0.001	0.081	0.135	0.038	0.191
10T4-3	0.025	0.001	0.119	0.198	0.011	0.32
10T11-1	0.033	0.002	0.006	0.010	0.24	0.015
10T11-2	0.042	0.003	0.003	0.005	0.31	0.006

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

-- = data cannot be extrapolated.

TABLE I-11. 76 Hz TRANSVERSE ELECTRIC FIELD INTENSITIES (V/m)
 Bird Species and Community Studies
 Data Extrapolated to 150 Ampere Current
 Michigan Transects

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations	
	NS	NEW	SEW	NS	EW
10C1-2	--	--	--	--	--
10C1-3	--	--	--	--	--
10C2-1	--	--	--	--	--
10C2-2	--	--	--	--	--
10C5-2	--	--	--	--	--
10C5-3	--	--	--	--	--
10C12-1	--	--	--	--	--
10C12-2	--	--	--	--	--
10C13-1	--	--	--	--	--
10C13-2	--	--	--	--	--
10T1-1	--	--	--	0.050	--
10T1-3	0.075	--	--	0.070	--
10T1-4	--	--	--	0.040	--
10T1-5	--	--	--	0.030	--
10T2-1	0.075	--	--	0.060	--
10T2-2	0.075	--	--	0.070	--
10T2-4	0.075	--	--	0.070	--
10T3-1	0.150	--	--	0.050	0.030
10T3-2	0.150	--	0.025	0.060	0.030
10T3-3	0.188	--	0.43	0.050	0.090
10T4-1	0.075	--	0.075	0.030	0.060
10T4-3	--	--	0.075	0.010	0.080
10T11-1	--	--	--	0.040	0.020
10T11-2	--	--	--	0.38	0.090

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

TABLE I-12. 76 Hz LONGITUDINAL ELECTRIC FIELD INTENSITIES (mV/m)
Bird Species and Community Studies
Data Extrapolated to 150 Ampere Current
Michigan Transects

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations	
	NS	NEW	SEW	NS	EW
10C1-2	0.150	0.075	0.100	0.150	0.120
10C1-3	0.49	0.100	0.050	0.49	0.110
10C2-1	0.64	0.050	0.175	0.73	0.21
10C2-2	0.41	0.075	0.175	0.37	0.20
10C5-2	0.038	0.075	0.175	0.140	0.23
10C5-3	0.188	0.075	0.23	0.170	0.27
10C12-1	1.05	0.25	0.28	0.68	0.28
10C12-2	0.150	0.075	0.100	0.150	0.120
10C13-1	0.90	0.68	2.6	0.57	2.4
10C13-2	0.90	0.58	2.5	0.89	2.9
10T1-1	32	0.70	0.20	28	0.150
10T1-3	83	1.70	1.93	71	1.47
10T1-4	36	0.75	0.78	41	0.87
10T1-5	24	0.50	0.150	23	0.150
10T2-1	53	1.08	1.93	53	2.5
10T2-2	63	1.40	2.7	70	3.4
10T2-4	22	1.40	4.0	50	4.9
10T3-1	31	5.8	15.0	49	21
10T3-2	47	3.3	26	54	27
10T3-3	51	--	90	48	75
10T4-1	33	3.4	40	24	48
10T4-3	17.3	3.5	48	13.0	81
10T11-1	25	6.8	14.8	39	19.7
10T11-2	52	23	11.0	73	29

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

**TABLE I-13. 76 Hz MAGNETIC FLUX DENSITIES (mG)
Bird Species and Community Studies
Data Extrapolated to 150 Ampere Current
Michigan Transects**

Site No., Meas. Pt.	1986 Extrapolations			1987 Extrapolations	
	NS	NEW	SEW	NS	EW
10C1-2	--	--	--	--	--
10C1-3	--	--	--	--	--
10C2-1	--	--	--	0.010	0.010
10C2-2	--	--	--	0.010	--
10C5-2	--	--	--	--	0.010
10C5-3	--	--	--	--	--
10C12-1	--	--	--	--	--
10C12-2	--	--	--	--	--
10C13-1	--	--	--	0.010	0.020
10C13-2	--	--	--	--	0.010
10T1-1	1.65	0.025	--	1.79	0.010
10T1-3	1.76	0.025	0.175	1.76	0.010
10T1-4	0.98	0.025	0.025	1.03	0.020
10T1-5	1.28	0.025	0.025	4.9	0.020
10T2-1	2.5	0.050	0.025	2.5	0.010
10T2-2	1.61	0.025	0.025	1.65	0.020
10T2-4	0.98	0.025	0.025	0.97	0.020
10T3-1	1.09	0.075	0.175	1.88	0.150
10T3-2	3.0	0.050	0.33	2.9	0.31
10T3-3	4.4	10.0	14.5	1.96	8.9
10T4-1	0.94	0.025	2.0	0.38	1.91
10T4-3	0.94	0.025	3.0	0.110	3.2
10T11-1	1.24	0.050	0.150	2.4	0.150
10T11-2	1.58	0.075	0.075	3.1	0.060

NS = north-south antenna element.

NEW = northern east-west antenna element.

SEW = southern east-west antenna element.

EW = both east-west antenna elements (operational configuration).

-- = data cannot be extrapolated from measurements lower than the probe's minimum sensitivity.

The 1987 60 Hz measurements at test transects showed the same general trends in field magnitudes as were reported in 1986 as the result of 60 Hz signals from power lines coupled onto the ELF antenna elements. That is, the 60 Hz magnetic flux densities increased and the longitudinal electric fields decreased near the antenna wires in comparison to measurements made prior to antenna construction. However, 1987 60 Hz magnetic field levels were about two times greater than those measured in 1986 along transects 10T1 and 10T2, and about two times lower along 10T3. This is likely the result of several factors. For example, the antenna elements were not grounded at the transmitters during the 60 Hz measurements in 1987 as they were in 1986. This may change the amount of 60 Hz coupling to the antenna elements, as is explained in Section 3.5.2.2 of this report. Other changes in the 60 Hz coupling may result from changes in power line loads and changes in earth conductivity as a function of soil moisture.

The EM fields generated by the 60 Hz current on the antenna wire are localized near the antenna and do not affect the 60 Hz fields at the control transects. All 60 Hz EM field measurements at the control transects for 1987 remained consistent with previous years' measurements.

The 1987, 76 Hz longitudinal electric fields at control transects in Michigan were consistent with those measured in 1986. The 76 Hz transverse electric field and magnetic flux densities were often below probe sensitivities at control transects, so similar comparisons could not be made.

In 1987, the longitudinal electric field and magnetic flux measured at test transects during operation of the east-west antenna element were consistently lower than those measured in 1986, with the exception of a few measurement points at transects 10T3 and 10T4, which are near the east-west antenna element.

During the operation of the north-south antenna element the transverse and longitudinal electric fields changed little between 1986 and 1987, while changes of a factor of two or more were seen in the magnetic flux under these conditions at measurement points 10T1-5 and 10T3-3 and at transect 10T4.

Changes in the operational status of the MTF between 1986 and 1987 and their relationship to 76 Hz field intensities are discussed in Section 3.5.2.3 of this report.

APPENDIX J
EM EXPOSURE CRITERIA

EM EXPOSURE CRITERIA

Because the electromagnetic (EM) intensity and operational characteristics required to produce a bioeffect are not known, EM exposure criteria were established to assist investigators in selecting study sites. The exposure criteria ensure that the 76 Hz EM fields at a test site are significantly larger than the 76 Hz EM fields at the control site, the 60 Hz fields at the test site, and the 60 Hz fields at the control site. In addition, the exposure criteria verify that there is not a substantial difference in the ambient 60 Hz EM field between the test and control sites.

The EM exposure criteria used in site selection are expressed in equation form as follows:

$$T (76 \text{ Hz}) / C (76 \text{ Hz}) > 10 \quad (1)$$

$$T (76 \text{ Hz}) / T (60 \text{ Hz}) > 10 \quad (2)$$

$$T (76 \text{ Hz}) / C (60 \text{ Hz}) > 10 \quad (3)$$

$$0.1 < T (60 \text{ Hz}) / C (60 \text{ Hz}) < 10 \quad (4)$$

where: T (76 Hz) = Test site exposure due to ELF system
T (60 Hz) = Test site exposure due to power lines
C (76 Hz) = Control site exposure due to ELF system
C (60 Hz) = Control site exposure due to power lines

Based on the exposure assessment, each possible test and control site pairing was classified as acceptable, conditionally acceptable, or unacceptable. These categories are defined as follows:

Acceptable. A test/control site pair was placed in this category if it satisfied all four EM exposure inequalities for each of the EM fields applicable to the study. For example, the small mammals and nesting birds studies would be concerned with both the soil and air electric fields as well as the magnetic fields. The soil arthropods and earthworms studies, however, would not be concerned with the electric field in the air, since this field terminates at the earth's surface and would not be expected to impact biota existing in the soil or litter layer.

Conditionally Acceptable. A test/control site pair was placed in this category if it approached, but did not meet, the criteria for acceptability. This category was established since the EM exposure criteria were not rigidly defined. The assumption that a difference of one order of magnitude or more would constitute a significant difference between test and control sites was chosen for these studies, but without knowing what effects will be experienced, if any. It is difficult to define this difference a priori. Furthermore, the EM field measurements themselves encompass a certain degree of error, as do any physical measurements.

Unacceptable. A test/control site pair was placed in this category if it neither satisfied the criteria for acceptability nor qualified for conditional acceptability.

APPENDIX K
EM MEASUREMENTS VS. WTF ANTENNA PHASE

EM MEASUREMENTS VS. WTF ANTENNA PHASE

Tables K-1 through K-6 document EM field measurements as a function of the Wisconsin Transmitting Facility (WTF) antenna current phase angle for study sites 8A2-6, 8M3-1, 8M4-1, 10T6-2, 10T8-4, and 10T10-1, respectively.

These data can be used to relate measurements taken in previous years to measurements at any antenna current phase angle. They may also be used to estimate the field levels at phase angles for which measurements have not been made. For the longitudinal electric field, the data tables also give a correction factor that can be used to calculate the maximum field magnitude from the vector sum magnitude for the measured phase angles. Correction factors for other phase angles can be linearly extrapolated from those in the tables. This has already been done for -75° , the most commonly used WTF condition.

TABLE K-1. EM MEASUREMENTS VS. ANTENNA PHASE FOR 8A2-6

Site No., Meas. Pt.	Antenna Current Phase,* Degrees	Longitudinal Electric Field Intensity (mV/m)		Correction Factor: E _{MAX} /E _{VS}	Magnetic Flux Density (mG)	
		Vector Sum E _{VS}	Measured Max. E _{MAX}		Vector Sum B _{VS}	Vertical Component B _{Vert.}
8A2-6	NS only	189	195	1.03	7.1	7.1
	EW only	66	67	1.02	0.27	0.26
	0	137	138	1.01	7.3	7.3
	-30	131	131	1.00	7.3	7.3
	-60	147	143	0.97	7.2	7.2
	-75			1.01		
	-90	160	168	1.05	7.2	7.2
	-120	210	210	1.00	7.1	7.1
	-150	230	240	1.04	7.0	6.9
	-180	250	250	1.00	6.8	6.7
	-210	250	250	1.00	6.9	6.8
	-240	240	250	1.04	6.9	6.8
	-270	220	230	1.04	7.0	6.9
	-300	190	195	1.03	7.1	7.1
	-330	160	168	1.05	7.2	7.2

*Defined as the phase of the NS antenna current with respect to the EW antenna current.

TABLE K-2. EM MEASUREMENTS VS. ANTENNA PHASE FOR 8M3-1

Site No., Meas. Pt.	Antenna Current Phase,* Degrees	Longitudinal Electric Field Intensity (mV/m)		Correction Factor: E _{MAX} /E _{VS}	Magnetic Flux Density (mG)	
		Vector Sum E _{VS}	Measured Max. E _{MAX}		Vector Sum B _{VS}	Vertical Component B _{Vert.}
8M3-1	NS only	10.6	10.5	0.99	0.079	0.051
	EW only	4.8	5.0	1.04	0.035	0.0167
	0	9.2	8.5	0.92	0.106	0.064
	-30	7.7	7.8	1.01	0.109	0.068
	-60	7.3	7.6	1.04	0.103	0.066
	-75			1.01		
	-90	8.4	8.3	0.99	0.094	0.062
	-120	10.2	10.2	1.00	0.082	0.056
	-150	12.3	12.0	0.98	0.069	0.047
	-180	13.5	13.6	1.01	0.060	0.038
	-210	14.7	14.6	0.99	0.059	0.035
	-240	14.9	14.5	0.97	0.068	0.037
	-270	14.2	13.6	0.96	0.080	0.046
	-300	13.0	12.0	0.92	0.093	0.054
	-330	11.2	10.2	0.91	0.101	0.060

*Defined as the phase of the NS antenna current with respect to the EW antenna current.

TABLE K-3. EM MEASUREMENTS VS. ANTENNA PHASE FOR 8M4-1

Site No., Meas. Pt.	Antenna Current Phase,* Degrees	Longitudinal Electric Field Intensity (mV/m)		Correction Factor: E _{MAX} /E _{VS}	Magnetic Flux Density (mG)	
		Vector Sum E _{VS}	Measured Max. E _{MAX}		Vector Sum B _{VS}	Vertical Component B _{Vert.}
8M4-1	NS only	6.6	6.5	0.98	0.095	0.051
	EW only	3.0	3.0	1.00	0.058	0.022
	0	5.2	5.2	1.00	0.062	0.034
	-30	5.0	4.6	0.92	0.061	0.027
	-60	5.9	5.0	0.85	0.078	0.032
	-75			0.88		
	-90	6.8	6.1	0.90	0.102	0.042
	-120	7.8	7.3	0.94	0.121	0.053
	-150	8.5	8.4	0.99	0.136	0.060
	-180	8.9	8.8	0.99	0.144	0.065
	-210	8.8	8.9	1.01	0.145	0.069
	-240	8.4	8.5	1.01	0.135	0.066
	-270	7.6	7.2	0.95	0.122	0.062
	-300	6.7	6.7	1.00	0.099	0.052
	-330	5.7	5.7	1.00	0.076	0.041

*Defined as the phase of the NS antenna current with respect to the EW antenna current.

TABLE K-4. EM MEASUREMENTS VS. ANTENNA PHASE FOR 10T6-2

Site No., Meas. Pt.	Antenna Current Phase,* Degrees	Longitudinal Electric Field Intensity (mV/m)		Correction Factor: E _{MAX} /E _{VS}	Magnetic Flux Density (mG)	
		Vector Sum E _{VS}	Measured Max. E _{MAX}		Vector Sum B _{VS}	Vertical Component B _{Vert.}
10T6-2	NS only	14.1	15.0	1.06	0.082	0.049
	EW only	95	95	1.00	7.8	7.7
	0	95	95	1.00	7.8	7.7
	-30	95	95	1.00	7.8	7.7
	-60	93	95	1.02	7.8	7.7
	-75			1.02		
	-90	93	95	1.02	7.8	7.7
	-120	93	95	1.02	7.8	7.7
	-150	92	95	1.03	7.8	7.7
	-180	95	95	1.00	7.8	7.7
	-210	95	95	1.00	7.8	7.7
	-240	97	95	0.98	7.8	7.7
	-270	97	95	0.98	7.8	7.7
	-300	97	95	0.98	7.8	7.7
	-330	96	95	0.99	7.8	7.7

*Defined as the phase of the NS antenna current with respect to the EW antenna current.

TABLE K-5. EM MEASUREMENTS VS. ANTENNA PHASE FOR 10T8-4

Site No., Meas. Pt.	Antenna Current Phase,* Degrees	Longitudinal Electric Field Intensity (mV/m)		Correction Factor: E_{MAX}/E_{VS}	Magnetic Flux Density (mG)	
		Vector Sum E_{VS}	Measured Max. E_{MAX}		Vector Sum B_{VS}	Vertical Component $B_{VERT.}$
10T8-4	NS only	85	82	0.96	3.4	3.4
	EW only	23	24	1.02	0.192	0.160
	0	88	84	0.95	3.7	3.6
	-30	84	82	0.98	3.7	3.6
	-60	84	80	0.95	3.7	3.6
	-75			0.95		
	-90	86	82	0.95	3.6	3.5
	-120	86	82	0.95	3.6	3.5
	-150	89	82	0.92	3.3	3.3
	-180	91	90	0.99	3.5	3.4
	-210	91	93	1.02	3.3	3.3
	-240	91	94	1.03	3.5	3.4
	-270	91	90	0.99	3.5	3.4
	-300	85	85	1.00	3.6	3.5
	-330	88	84	0.95	3.6	3.5

*Defined as the phase of the NS antenna current with respect to the EW antenna current.

TABLE K-6. EM MEASUREMENTS VS. ANTENNA PHASE FOR 10T10-1

Site No., Meas. Pt.	Antenna Current Phase,* Degrees	Longitudinal Electric Field Intensity (mV/m)		Correction Factor: E_{MAX}/E_{VS}	Magnetic Flux Density (mG)	
		Vector Sum E_{VS}	Measured Max. E_{MAX}		Vector Sum B_{VS}	Vertical Component $B_{Vert.}$
10T10-1	NS only	77	82	1.06	4.5	4.5
	EW only	10.5	10.5	1.00	0.066	0.030
	0	79	80	1.01	4.5	4.5
	-30	80	83	1.04	4.5	4.5
	-60	80	84	1.05	4.5	4.5
	-75			1.05		
	-90	80	84	1.05	4.5	4.5
	-120	79	83	1.05	4.5	4.5
	-150	78	81	1.04	4.6	4.6
	-180	78	81	1.04	4.6	4.6
	-210	78	82	1.05	4.6	4.6
	-240	78	82	1.05	4.6	4.6
	-270	78	81	1.04	4.6	4.6
	-300	78	80	1.03	4.6	4.6
	-330	79	80	1.01	4.5	4.5

*Defined as the phase of the NS antenna current with respect to the EW antenna current.

APPENDIX L

**EM EXPOSURE SETUP PROTOCOLS FOR SOIL AMOEBA
AND SLIME MOLD STUDIES**

EM EXPOSURE SETUP PROTOCOLS FOR SOIL AMOEBA AND SLIME MOLD STUDIES

This appendix documents the protocols written by IITRI to assist the soil amoeba and slime mold study investigators in setting up their study sites using the culture cell exposure hardware fabricated by IITRI. These protocols also provide guidelines for proper adjustment of the EM exposures and monitoring of the exposure parameters using this equipment.

EXPOSURE SETUP PROTOCOLS FOR SOIL AMOEBA STUDIES

MATCHED ELECTRIC FIELD PROTOCOL

- (1) Measure maximum electric field in soil using 1 meter probe, E .
- (2) Multiply electric field value by 0.15 to determine the minimum required drive voltage, V_{DR} (min).

$$V_{DR} (\text{min}) = E \times 0.15 (\text{volts})$$

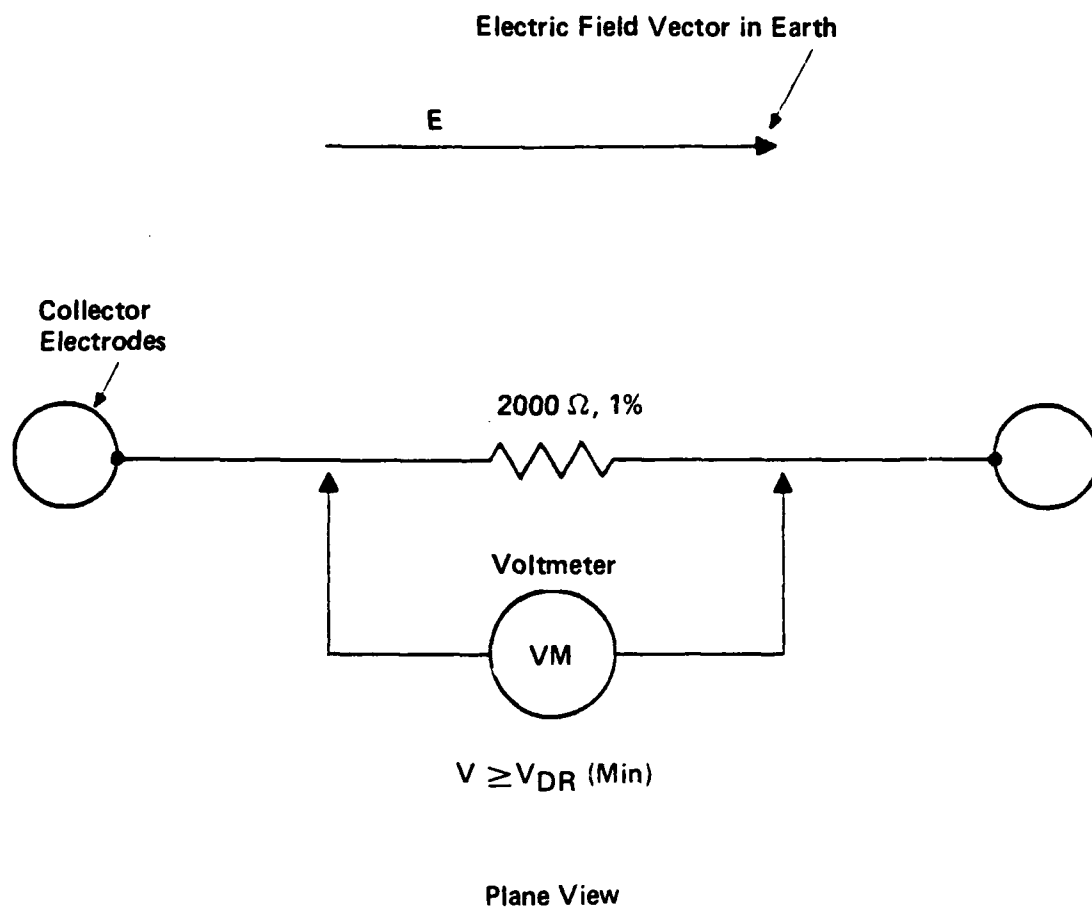
- (3) Locate collector electrodes in line with the maximum electric field in the earth, and spaced far enough apart to generate a voltage across a 2000 ohm resistor that is greater than or equal to V_{DR} (min) (see Figure L-1).
- (4) Measure and record electrode spacing and the open circuit (no load) electrode voltage, V_{OC} .
- (5) Connect the test cell and monitoring box to the electrodes (see Figure L-2). While monitoring the voltage across the test cell only, V_{CL} , adjust the variable resistor so that the cell voltage is equal to the value given by the following formula:

$$V_{CL} = E \times 0.113 (\text{volts})$$

- (6) With the cell voltage set, measure and record the voltage across the 100 ohm series resistor, V_R . This allows calculation of the cell current and current density.
- (7) Measure and record the electrode voltage with the test cell and monitoring box connected and adjusted as per Step 5, V_{DR} .

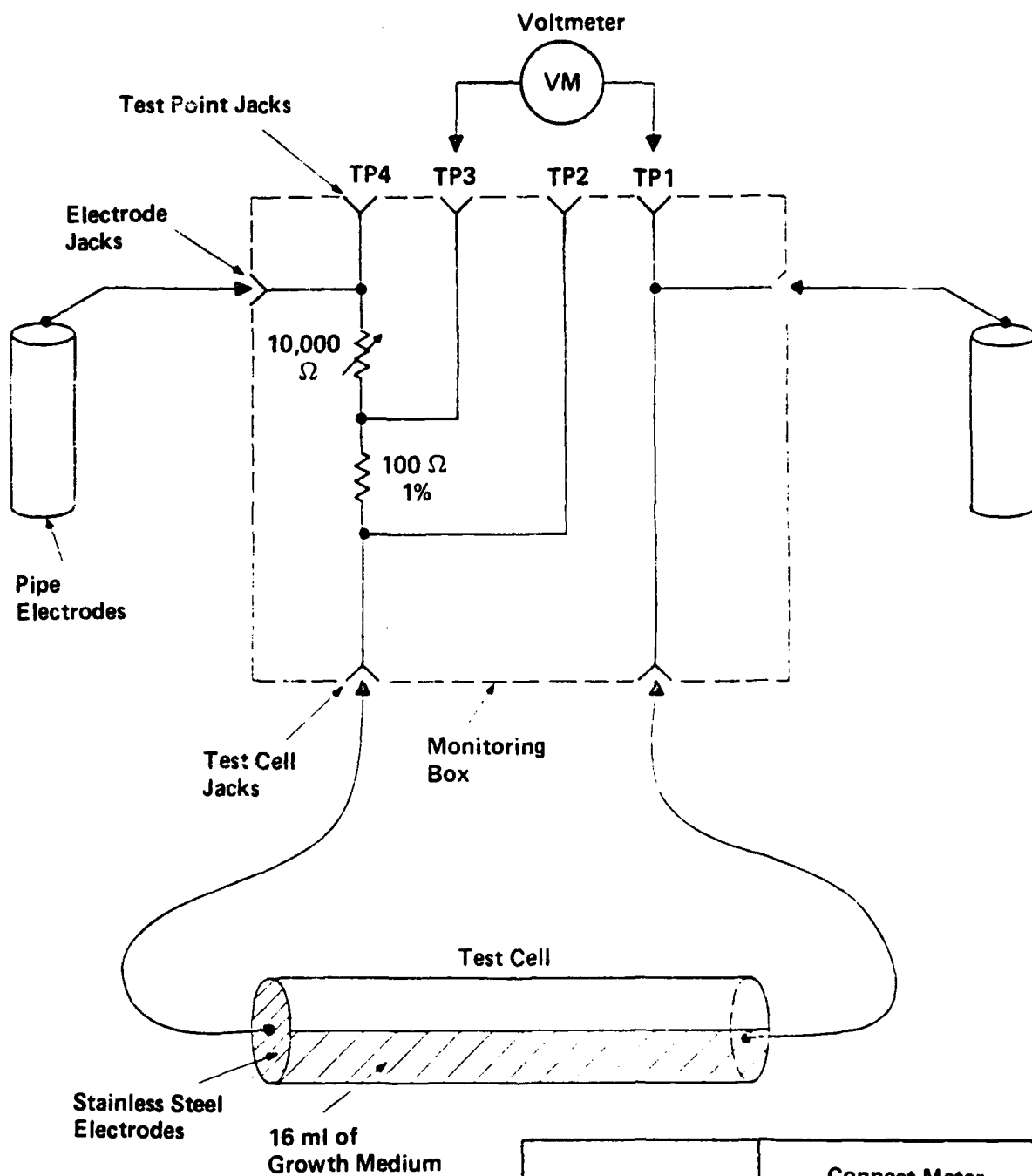
MATCHED CURRENT DENSITY PROTOCOL

- (1) Measure maximum electric field in soil using 1 meter probe, E .
- (2) Locate collector electrodes in line with maximum electric field with a separation of 1 meter.
- (3) Measure exact electrode spacing and open circuit (no load) electrode voltage, V_{OC} . Measured voltage should be within a few percent of that measured in Step 1. If not, correct electrode spacing as appropriate.



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FIGURE L-1. DETERMINATION OF DRIVE VOLTAGE FOR THE SOIL AMOEBA STUDIES MATCHED ELECTRIC FIELD PROTOCOL.



To Measure	Connect Meter Across
V_{CL}	TP1 – TP2
V_R	TP2 – TP3
V_{DR}	TP1 – TP4

FIGURE L-2. TEST CHAMBER HOOKUP FOR THE SOIL AMOEBA STUDIES
MATCHED ELECTRIC FIELD PROTOCOL.

- (4) Connect current-limiting test chamber (see Figure L-3) to electrodes. Place the current limit select switch to the 2.5 megohm position (2.5 M).
- (5) Measure and record the voltages across the test cell, V_{CL} , the resistor, V_R , and the electrodes, V_{DR} , using the test point jacks (see Figure L-3 for test point numbering).

The voltages across the resistor and across the electrodes should be close in value to V_{OC} from Step 3.

$$V_R \approx V_{DR} \approx V_{OC}$$

The voltage across the test cell will be much lower, and can be estimated as:

$$V_{CL} \approx 0.6 \times 10^{-3} \times V_{OC} \text{ (volts).}$$

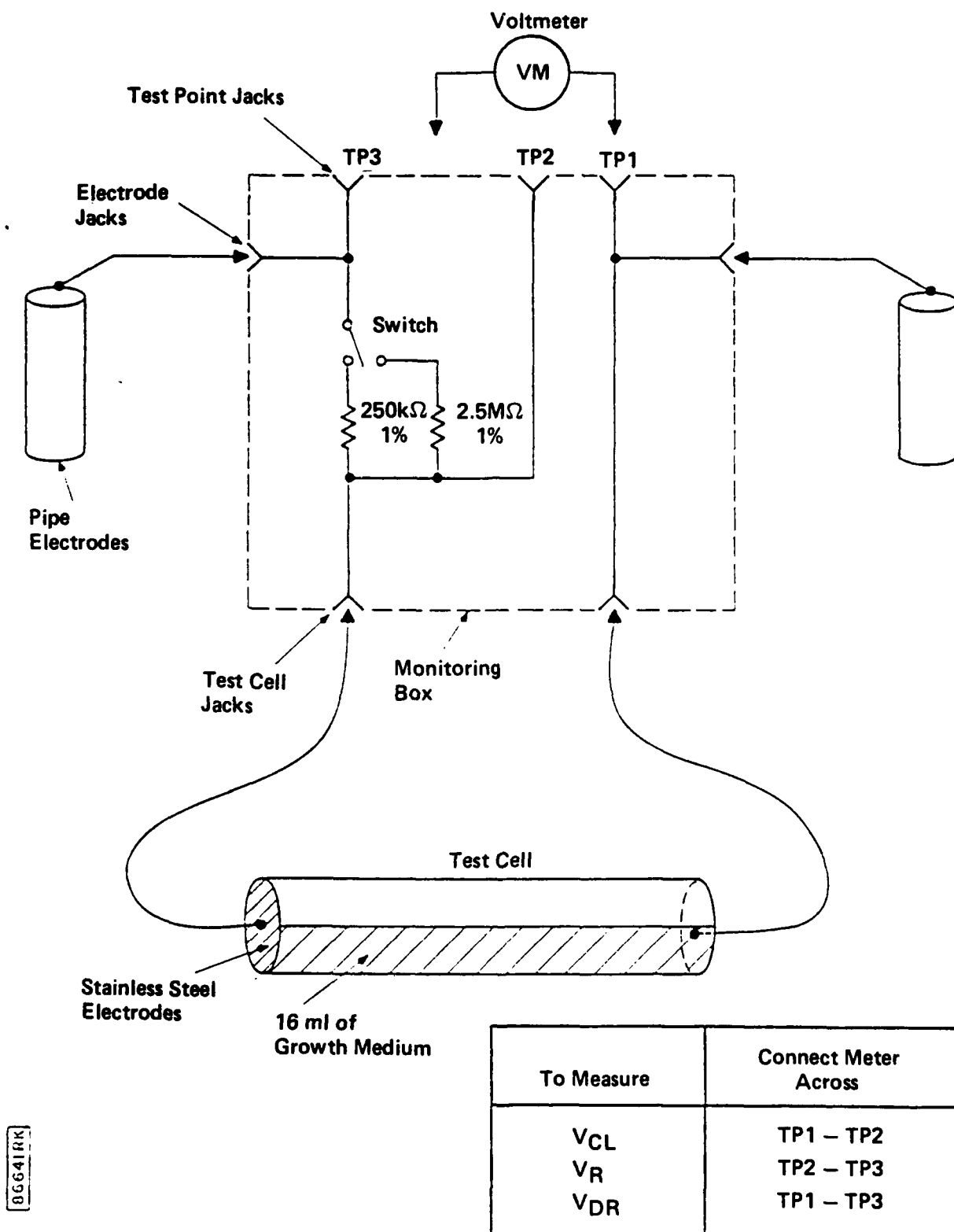


FIGURE L-3. TEST CHAMBER HOOKUP FOR THE SOIL AMOEBA STUDIES MATCHED CURRENT DENSITY PROTOCOL.

EXPOSURE SETUP PROTOCOLS FOR SLIME MOLD STUDIES

MATCHED ELECTRIC FIELD PROTOCOL

- (1) Measure maximum electric field in soil with 1 meter probe, E.
- (2) Multiply electric field value by 0.2 to determine the minimum required chamber voltage, V_{CH} (min).

$$V_{CH} \text{ (min)} = E \times 0.2 \text{ (volts)}$$

- (3) Locate collector electrodes in line with maximum electric field in the earth and spaced far enough apart to generate a voltage across a 1000 ohm resistor that is greater than or equal to V_{CH} (min) (see Figure L-4).
- (4) Measure and record electrode spacing and open circuit (no load) voltage, V_{OC} .
- (5) Connect test chamber to electrodes. Connect voltmeter to measure voltage across test cell, V_{CL} (see Figure L-5). Adjust variable resistor (Pot) so that the voltage across the test cell is equal to V_{CL} as determined by the formula:

$$V_{CL} = E \times 0.155 \text{ (volts)}$$

- (6) Measure and record the voltage across the 100 ohm series resistor, V_R (see Figure L-5). This allows calculation of the cell current and current density.
- (7) Measure and record the voltage between the electrodes, V_{CH} , with the test chamber connected and adjusted as per Step 5.

MATCHED CURRENT DENSITY PROTOCOL

- (1) Measure maximum electric field in soil using 1 meter probe, E.
- (2) Locate collector electrodes in line with maximum electric field with a separation of 1 meter.

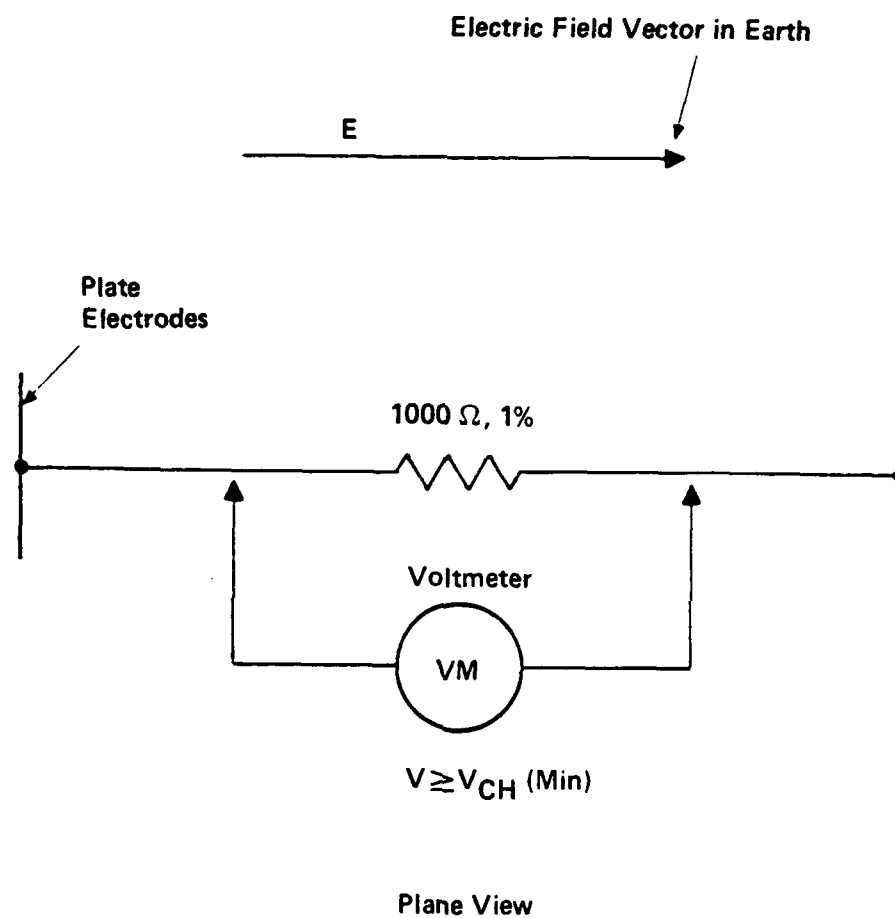
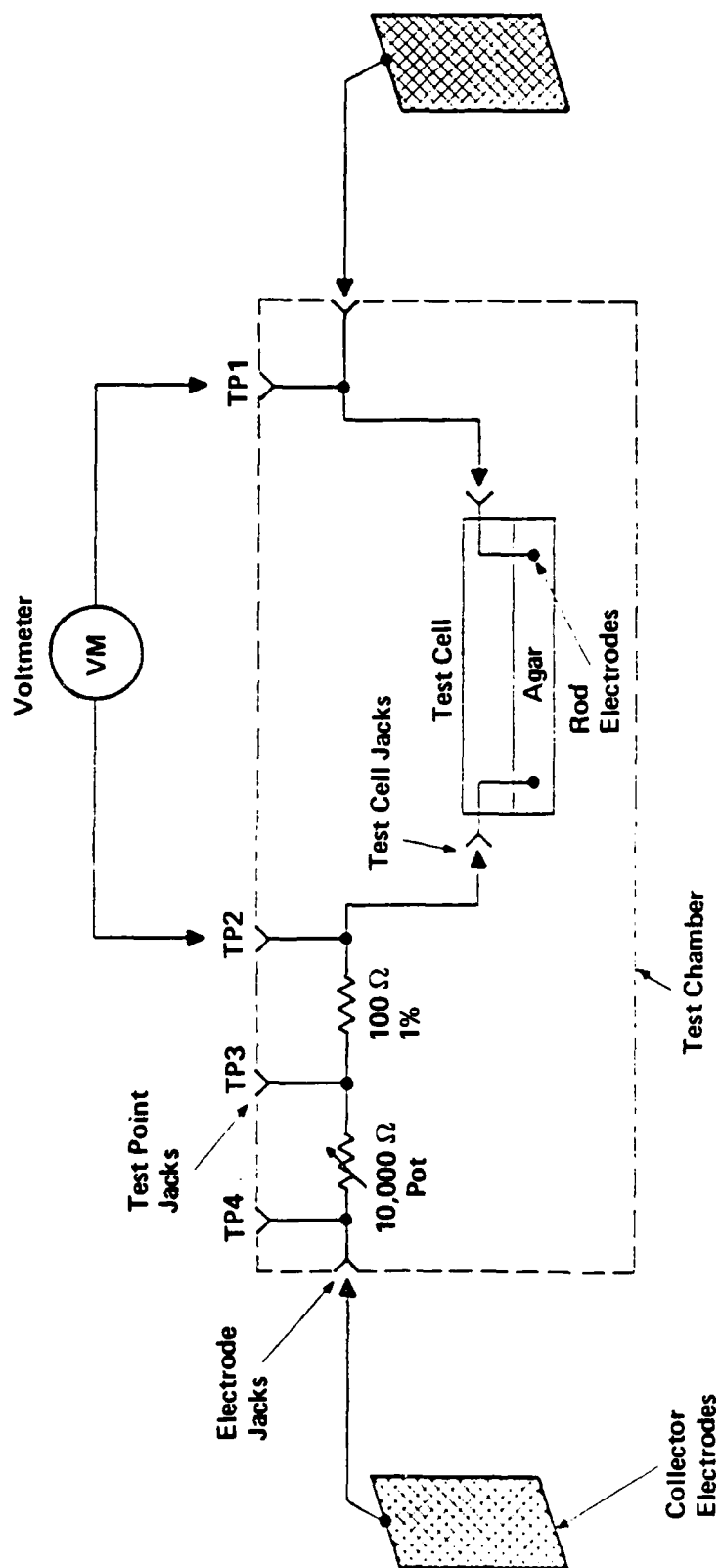


FIGURE L-4. DETERMINATION OF CHAMBER VOLTAGE FOR THE SLIME MOLD STUDIES MATCHED ELECTRIC FIELD PROTOCOL.



Test Number	Connect Voltmeter Across
4 V _{OC}	Collector Electrodes
5 V _{CL}	TP1 - TP2
6 V _R	TP2 - TP3
7 V _{CH}	TP1 - TP4

FIGURE L-5. TEST CHAMBER HOOKUP FOR THE SLIME MOLD STUDIES MATCHED ELECTRIC FIELD PROTOCOL.

- (3) Measure exact electrode spacing and open circuit (no load) electrode voltage, V_{OC} . Measured voltage should be within a few percent of that measured in Step 1. If not, correct electrode spacing as appropriate.
- (4) Connect current-limiting test chamber (see Figure L-6) to electrodes. Place the current limit select switch to the 500 kilohm position (500 K).
- (5) Measure and record the voltages across the test cell, V_{CL} , the resistor, V_R , and the test chamber, V_{CH} , using the test point jacks (see Figure L-6 for test point numbering).

The voltages across the resistor and across the test chamber should be close in value to V_{OC} from Step 3.

$$V_R \approx V_{CH} \approx V_{OC}$$

The voltage across the test cell will be much lower, and can be estimated as:

$$V_{CL} \approx 1.6 \times 10^{-3} \times V_{OC} \text{ (volts).}$$

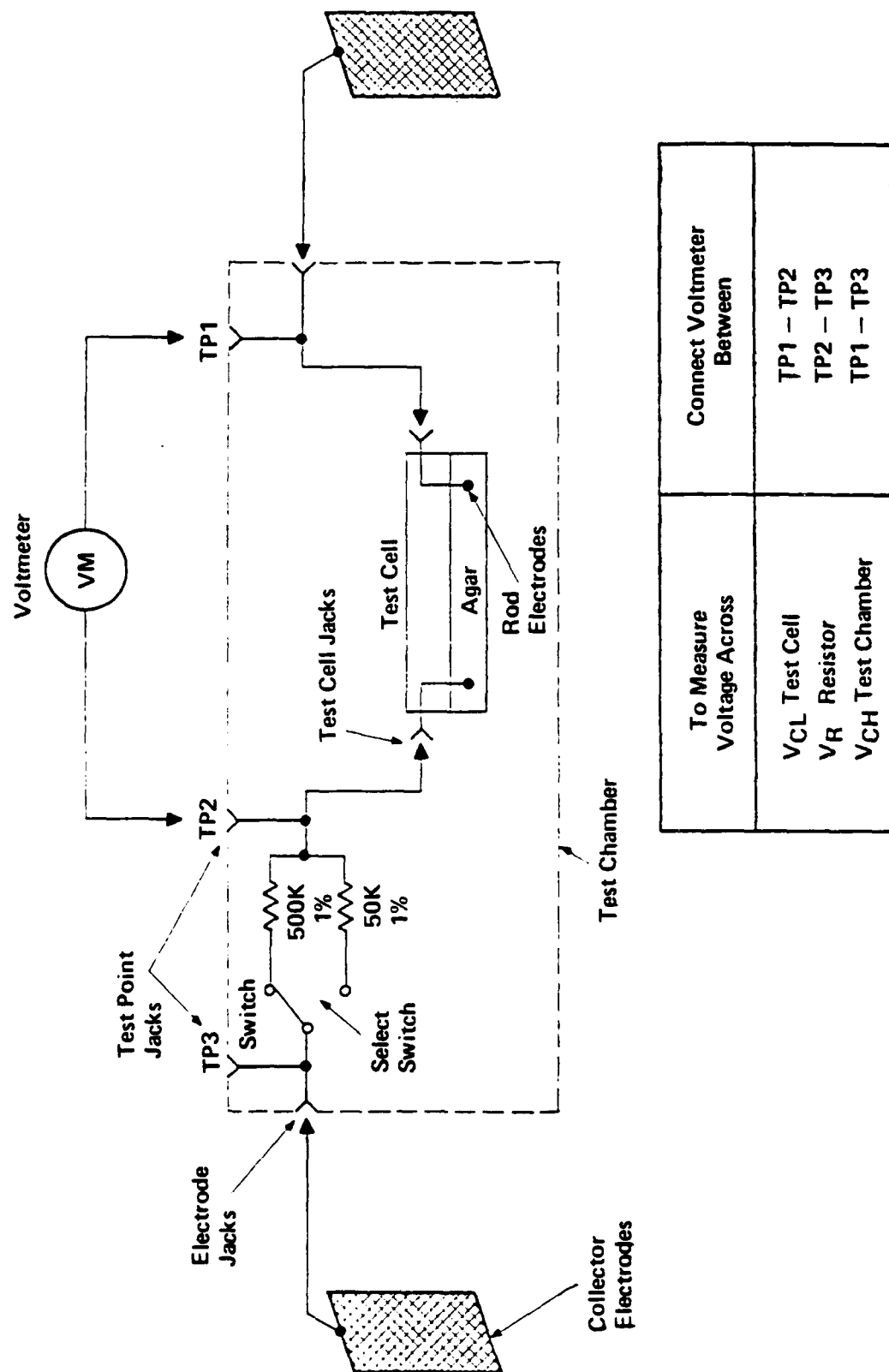


FIGURE L-6. TEST CHAMBER HOOKUP FOR THE SLIME MOLD STUDIES MATCHED CURRENT DENSITY PROTOCOL.

APPENDIX M
SUMMARY OF WISCONSIN AND MICHIGAN
TRANSMITTING FACILITY OPERATION

SUMMARY OF WISCONSIN AND MICHIGAN TRANSMITTING FACILITY OPERATION

The operations of the Wisconsin and Michigan Transmitting Facilities (WTF and MTF) during 1984-1987 have been summarized in response to requests from investigators for information on operating schedules. The summary is partitioned differently for the WTF and MTF because of differences in their operating modes. The WTF is partitioned according to antenna element, modulation, and frequency. The MTF is partitioned according to antenna element, modulation, and antenna current. Discussion and presentation of data from the WTF appear below, followed by the same for the MTF.

The WTF operating schedule has been broken down into three antenna conditions: north-south antenna element, east-west antenna element, and both antenna elements. The north-south antenna element data represent those times when the north-south antenna element was operating while the east-west antenna element was off; the east-west antenna element data represent those times when the east-west antenna element was operating while the north-south antenna element was off; and the "both antenna elements" data represent only those times when the north-south antenna element and the east-west antenna element were operating simultaneously.

Tables M-1, M-2, and M-3 show the number of hours of operation per month in 1984 for the north-south, east-west, and both antenna elements, respectively. Equivalent data for 1985 through 1987 are presented in Tables M-4 through M-12. The columns on these tables, labeled with the calendar months, provide a breakdown of the WTF operation by frequency and signal type. Subtotals are given by signal type. A monthly total is also provided. Yearly total hours of operation by signal type and frequency are given in the "Annual Totals" column.

The bottom row of the tables gives the number of "changes in operational mode" of the antenna element(s) on a monthly and annual basis. These data represent any change in the transmitter facility operating condition. This would include an initial power up and changes in the antenna current, phase (when both antennas are powered), frequency, and modulation scheme. It does not include the powering down of antenna elements.

TABLE M-1. 1984 WTF OPERATIONS SUMMARY: NORTH-SOUTH ANTENNA ELEMENT ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
76	0.94	107.19	--	1.98	7.24	13.85	--	22.10	8.07	1.69	30.17	1.48	194.71
Mode: <u>Modulated Signal^a</u>													
44	--	1.69	0.05	0.55	0.66	--	0.58	--	1.75	0.08	--	--	5.36
72	0.64	8.65	--	--	0.52	0.30	0.07	16.40	1.50	0.28	0.32	--	28.68
76	3.91	0.21	0.30	4.46	10.35	6.09	11.44	158.38	116.88	9.29	2.28	--	323.59
80	0.81	3.12	1.79	1.06	--	--	0.01	1.97	2.69	2.40	2.91	--	16.76
Subtotals	5.36	13.67	2.14	6.07	11.53	6.39	12.10	176.75	122.82	12.05	5.51	--	374.39
Other ^b	--	0.34	0.21	0.62	0.59	--	--	--	0.05	1.38	0.13	--	3.32
Totals	6.30	121.20	2.35	8.67	19.36	20.24	12.10	198.85	130.94	15.12	35.81	1.48	572.42
Changes in Operational Mode	50	68	14	50	297	71	140	223	163	171	19	2	1268

^aFrequencies listed refer to the center frequency of modulation.

^bDenotes short periods of time at other frequencies or undesignated operation.

TABLE M-2. 1984 WTF OPERATIONS SUMMARY: EAST-WEST ANTENNA ELEMENT ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: <u>Modulated Signal</u> ^a													
44	--	--	--	--	0.82	--	--	--	--	--	--	--	0.82
76	0.64	13.94	18.81	0.92	7.90	0.05	1.45	0.02	2.41	0.33	0.22	0.04	46.73
Subtotals	0.64	13.94	18.81	0.92	8.72	0.05	1.45	0.02	2.41	0.33	0.22	0.04	47.55
Mode: <u>Unmodulated Signal</u>													
44	5.11	--	--	3.45	--	--	0.53	--	--	0.03	--	--	9.12
72	10.45	2.81	0.18	0.01	0.45	--	0.05	--	--	--	--	--	13.95
76	47.97	5.75	0.77	5.53	18.28	4.20	9.76	1.20	2.78	5.88	--	--	102.12
80	--	--	0.07	17.20	1.19	--	1.36	--	--	--	0.31	--	20.13
Subtotals	63.53	8.56	1.02	26.19	19.92	4.20	11.70	1.20	2.78	5.91	0.31	--	145.32
Other ^b	--	--	3.10	--	0.93	--	--	--	--	0.15	--	--	4.18
Totals	64.17	22.50	22.93	27.11	29.57	4.25	13.15	1.22	5.19	6.39	0.53	0.04	197.05
Changes in Operational Mode	55	32	13	36	273	48	152	50	80	131	3	1	874

^aFrequencies listed refer to the center frequency of modulation.

^bDenotes short periods of time at other frequencies or undesignated operation.

TABLE M-3. 1984 WTF OPERATIONS SUMMARY: NORTH-SOUTH AND
EAST-WEST ANTENNA ELEMENTS SIMULTANEOUSLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
	Mode: Modulated Signal ^a												
42	--	--	--	--	--	--	--	--	--	59.69	--	--	59.69
44	--	--	62.73	--	0.82	--	--	--	58.81	38.88	--	--	161.24
46	--	--	--	--	--	--	--	--	--	59.41	--	--	59.41
74	--	--	--	--	--	--	--	--	--	24.43	--	--	24.43
76	366.26	273.90	157.39	343.50	384.98	396.76	392.62	366.05	395.38	256.09	429.86	365.13	4127.92
78	--	--	--	--	--	--	--	--	43.37	--	--	--	43.37
Subtotals	366.26	273.90	220.12	343.50	385.80	396.76	392.62	366.05	497.56	438.50	429.86	365.13	4476.06
Mode: Unmodulated Signal													
44	--	--	--	--	0.10	--	--	--	--	0.35	--	--	0.45
72	4.14	2.71	2.43	4.05	3.89	2.44	1.88	5.61	2.36	2.64	2.49	3.33	37.97
76	0.03	--	0.05	1.04	3.12	0.05	1.54	42.54	18.03	1.20	0.16	--	67.76
80	4.75	2.70	0.57	2.99	2.13	2.57	2.77	3.61	2.81	1.22	1.85	1.62	29.59
Subtotals	8.92	5.41	3.05	8.08	9.24	5.06	6.19	51.76	23.20	5.41	4.50	4.95	135.77
Other ^b	--	--	0.26	--	0.51	--	--	0.03	0.81	1.28	--	--	2.89
Totals	375.18	279.31	223.43	351.58	395.55	401.82	398.81	417.84	521.57	445.19	434.36	370.08	4614.72
Changes in Operational Mode	67	40	41	85	144	67	79	264	181	94	68	76	1206

^aFrequencies listed refer to the center frequency of modulation.

^bDenotes short periods of time at other frequencies or undesignated operation.

TABLE M-4. 1985 WTF OPERATIONS SUMMARY: NORTH-SOUTH ANTENNA ELEMENT ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: <u>Modulated Signal</u> ^a													
44	--	--	3.41	0.86	0.50	--	--	--	--	--	--	--	4.77
76	0.15	--	3.83	3.21	3.15	3.09	--	1.98	76.31	27.12	--	--	118.84
78	--	--	--	0.33	--	--	--	--	1.87	--	--	--	2.20
Subtotals	0.15	--	7.24	4.40	3.65	3.09	--	1.98	78.18	27.12	--	--	125.81
Mode: <u>Unmodulated Signal</u>													
76	0.40	2.50	5.46	4.79	26.22	29.04	0.68	9.40	9.81	10.41	1.43	0.25	100.39
80	--	--	2.74	3.26	0.02	0.42	--	--	4.14	--	--	--	10.58
Subtotals	0.40	2.50	8.20	8.05	26.24	29.46	0.68	9.40	13.95	10.41	1.43	0.25	110.97
Other ^b	--	--	5.70	1.96	1.20	0.66	0.02	--	4.29	0.03	--	--	13.86
Totals	0.55	2.50	21.14	14.41	31.09	33.21	0.70	11.38	96.42	37.56	1.43	0.25	250.64
Changes in Operational Mode	18	2	32	56	126	115	15	51	42	15	3	1	476

^aFrequencies listed refer to the center frequency of modulation.

^bDenotes short periods of time at other frequencies or undesignated operation.

TABLE M-5. 1985 WTF OPERATIONS SUMMARY: EAST-WEST ANTENNA ELEMENT ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: Modulated Signal ^a													
44	--	--	3.15	3.07	1.34	1.62	--	--	0.34	--	--	--	9.52
76	0.85	--	7.30	14.82	20.69	1.28	142.27	2.23	2.17	3.02	0.03	--	194.66
78	--	--	1.64	0.93	--	--	--	--	0.32	--	--	--	2.89
Subtotals	0.85	--	12.09	18.82	22.03	2.90	142.27	2.23	2.83	3.02	0.03	--	207.07
Mode: Unmodulated Signal													
76	1.08	2.06	8.94	0.61	40.81	12.87	37.19	10.98	4.76	28.76	3.31	--	151.37
80	--	--	1.50	2.55	3.77	6.55	--	--	1.86	0.13	--	--	16.36
Subtotals	1.08	2.06	10.44	3.16	44.58	19.42	37.19	10.98	6.62	28.89	3.31	--	167.73
Other ^b	0.10	--	5.86	3.94	0.90	5.26	19.13	0.19	1.16	--	--	--	36.54
Totals	2.03	2.06	28.39	25.92	67.51	27.58	198.59	13.40	10.61	31.91	3.34	--	411.34
Changes in Operational Mode	46	1	74	80	143	223	31	59	45	22	3	0	727

^aFrequencies listed refer to the center frequency of modulation.

^bDenotes short periods of time at other frequencies or undesignated operation.

TABLE M-6. 1985 WTF OPERATIONS SUMMARY: NORTH-SOUTH AND
EAST-WEST ANTENNA ELEMENTS SIMULTANEOUSLY
[Hours of Operation]

Frequency, Hz	Hours of Operation												Annual Totals
	Month												
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: <u>Modulated Signal</u> ^a													
44	0.23	--	--	1.97	0.46	0.05	29.73	--	--	--	--	--	32.44
76	0.70	--	7.62	15.01	45.98	261.68	118.66	74.91	161.36	451.69	657.61	730.96	2526.18
78	--	--	--	0.99	--	0.05	73.94	--	0.43	--	--	--	75.41
Subtotals	0.93	--	7.62	17.97	46.44	261.78	222.33	74.91	161.79	451.69	657.61	730.96	2634.03
Mode: <u>Unmodulated Signal</u>													
76	0.34	--	10.16	90.06	10.35	10.70	--	1.63	4.82	3.40	0.61	--	132.07
80	--	--	--	9.80	--	0.98	--	--	--	1.72	--	--	12.50
Subtotals	0.34	--	10.16	99.86	10.35	11.68	--	1.63	4.82	5.12	0.61	--	144.57
Other ^b	0.13	--	25.48	43.63	0.31	0.22	10.87	--	0.03	--	--	--	80.67
Totals	1.40	--	43.26	161.46	57.10	273.68	233.20	76.54	166.64	456.81	658.22	730.96	2859.27
Changes in Operational Mode	13	0	14	60	55	69	15	48	20	54	38	38	424

^aFrequencies listed refer to the center frequency of modulation.

^bDenotes short periods of time at other frequencies or undesignated operation.

TABLE M-7. 1986 WTF OPERATIONS SUMMARY: NORTH-SOUTH ANTENNA ELEMENT ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
	Mode: Modulated Signal ^a												
76	40.51	11.81	1.37	3.13	0.16	21.20	7.65	3.33	1.88	0.01	0.05	0.94	92.04
Subtotal	40.51	11.81	1.37	3.13	0.16	21.20	7.65	3.33	1.88	0.01	0.05	0.94	92.04
	Mode: Unmodulated Signal												
72	0.00	0.00	0.00	0.29	1.86	0.00	0.00	0.00	0.15	0.00	0.00	0.00	2.30
76	0.00	0.00	0.00	1.22	0.30	0.00	0.00	0.00	0.17	3.28	0.00	0.00	4.97
80	0.00	0.00	0.00	0.42	1.33	0.00	0.00	0.12	0.08	0.00	0.00	0.00	1.95
Subtotals	0.00	0.00	0.00	1.93	3.49	0.00	0.00	0.12	0.40	3.28	0.00	0.00	9.22
Other ^b	0.00	0.00	0.00	0.00	1.46	0.00	0.00	0.00	0.19	0.00	0.00	0.00	1.65
Totals	40.51	11.81	1.37	5.06	5.11	21.20	7.65	3.45	2.47	3.29	0.05	0.94	102.91
Changes in Operational Mode	14	5	12	15	77	26	23	10	46	37	2	7	274

^aFrequencies listed refer to the center frequency of modulation.

^bDenotes short periods of time at other frequencies or undesignated operation.

TABLE M-8. 1986 WTF OPERATIONS SUMMARY: EAST-WEST ANTENNA ELEMENT ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: Modulated Signal ^a													
76	0.05	2.81	2.32	0.34	1.86	1.00	2.91	2.58	4.37	2.59	1.65	0.09	22.57
Subtotals	0.05	2.81	2.32	0.34	1.86	1.00	2.91	2.58	4.37	2.59	1.65	0.09	22.57
Mode: Unmodulated Signal													
72	0.00	0.00	0.00	0.66	1.74	0.00	0.02	0.00	0.00	0.00	0.00	0.00	2.42
76	0.00	0.00	1.10	0.21	1.38	0.00	0.08	0.00	0.00	3.36	0.09	0.00	6.22
80	0.00	0.00	0.00	0.80	0.56	0.00	0.01	0.00	0.00	0.00	0.00	0.00	1.37
Subtotals	0.00	0.00	1.10	1.67	3.68	0.00	0.11	0.00	0.00	3.36	0.09	0.00	10.01
Other ^b	0.00	0.00	0.00	0.00	1.50	0.00	0.00	0.00	0.15	0.00	0.00	0.00	1.65
Totals	0.05	2.81	3.42	2.01	7.04	1.00	3.02	2.58	4.52	5.95	1.74	0.09	34.23
Changes in Operational Mode	47	6	14	24	65	32	20	5	8	18	2	4	245

^aFrequencies listed refer to the center frequency of modulation.

^bDenotes short periods of time at other frequencies or undesignated operation.

TABLE M-9. 1986 WTF OPERATIONS SUMMARY: NORTH-SOUTH AND
EAST-WEST ANTENNA ELEMENTS SIMULTANEOUSLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
	Mode: <u>Modulated Signal^a</u>												
76	<u>672.44</u>	<u>633.09</u>	<u>600.27</u>	<u>595.68</u>	<u>656.56</u>	<u>641.07</u>	<u>689.94</u>	<u>633.20</u>	<u>675.58</u>	<u>688.85</u>	<u>696.57</u>	<u>679.21</u>	<u>7862.46</u>
Subtotals	672.44	633.09	600.27	595.68	656.56	641.07	689.94	633.20	675.58	688.85	696.57	679.21	7862.46
	Mode: <u>Unmodulated Signal</u>												
72	0.00	0.00	0.00	0.00	0.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.89
76	0.15	0.07	7.54	0.00	0.25	0.00	0.00	0.00	0.00	1.80	0.44	0.00	10.25
80	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.51</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.07</u>	<u>0.00</u>	<u>0.00</u>	<u>0.58</u>
Subtotals	0.15	0.07	7.54	0.00	1.65	0.00	0.00	0.00	0.00	1.87	0.44	0.00	11.72
Other ^b	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>1.48</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.33</u>	<u>0.00</u>	<u>0.00</u>	<u>0.34</u>	<u>2.15</u>
Totals	672.59	633.16	607.81	595.68	659.69	641.07	689.94	633.20	675.91	690.72	697.01	679.55	7876.33
Changes in Operational Mode	45	54	69	61	112	72	66	42	63	62	45	61	752

^aFrequencies listed refer to the center frequency of modulation.

^bDenotes short periods of time at other frequencies or undesignated operation.

TABLE M-10. 1987 WTF OPERATIONS SUMMARY: NORTH-SOUTH ANTENNA ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
Mode: Modulated Signal ^a													
76	11.03	0.07	0.00	0.09	0.38	0.40	1.88	0.24	0.00	2.13	1.09	0.00	17.31
Subtotals	11.03	0.07	0.00	0.09	0.38	0.40	1.88	0.24	0.00	2.13	1.09	0.00	17.31
Mode: Unmodulated Signal													
72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other ^b	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Totals	11.03	0.07	0.00	0.09	0.38	0.40	1.88	0.24	0.00	2.13	1.09	0.00	17.31
Changes in Operational Mode	19	0	2	0	6	8	32	1	1	5	5	1	80

^aFrequencies listed refer to the center frequency of modulation.

^bDenotes short periods of time at other frequencies or undesignated operation.

TABLE M-11. 1987 WTF OPERATIONS SUMMARY: EAST-WEST ANTENNA ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
	Mode: Modulated Signal ^a												
76	0.10	0.00	0.00	0.00	11.18	7.30	4.72	0.10	3.27	0.00	1.13	24.60	52.40
Subtotals	0.10	0.00	0.00	0.00	11.18	7.30	4.72	0.10	3.27	0.00	1.13	24.60	52.40
	Mode: Unmodulated Signal												
72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.17
76	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.00	0.23
Subtotals	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.45
Other ^b	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Totals	0.10	0.00	0.05	0.00	11.18	7.30	4.72	0.10	3.27	0.00	1.53	24.60	52.85
Changes in Operational Mode	6	2	1	2	67	6	9	5	3	3	39	5	148

^aFrequencies listed refer to the center frequency of modulation.

^bDenotes short periods of time at other frequencies or undesignated operation.

TABLE M-12. 1987 WTF OPERATIONS SUMMARY: NORTH-SOUTH AND
EAST-WEST ANTENNAS SIMULTANEOUSLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
	Mode: Modulated Signal ^a												
76	712.70	651.08	658.35	697.30	715.76	691.87	700.54	584.40	697.31	724.71	703.15	695.82	8232.99
Subtotals	712.70	651.08	658.35	697.30	715.76	691.87	700.54	584.40	697.31	724.71	703.15	695.82	8232.99
	Mode: Unmodulated Signal												
72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
76	1.77	0.00	0.00	0.00	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.53	2.76
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03
Subtotals	1.77	0.00	0.00	0.00	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.56	2.79
Other ^b	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38
Totals	714.85	651.08	658.35	697.30	716.22	691.87	700.54	584.40	697.31	724.71	703.15	696.38	8236.16
Changes in Operational Mode	32	10	11	10	13	14	24	23	13	10	12	12	184

^aFrequencies listed refer to the center frequency of modulation.

^bDenotes short periods of time at other frequencies or undesignated operation.

The MTF operating schedule was broken down into three antenna conditions in 1986 and two antenna conditions in 1987. The 1986 conditions were: north-south (NS) antenna element, north east-west (NEW) antenna element, and south east-west (SEW) antenna element. The 1987 conditions were: north-south antenna element and east-west (EW) antenna elements. The NS antenna element data represent those times when the NS element was operating while the NEW and SEW elements were off; the NEW antenna element data represent those times when the NEW element was operating while the NS and SEW elements were off; the SEW antenna element data represent those times when the SEW element was operating while the NS and NEW elements were off; the EW antenna element data represent those times when the NEW and SEW elements were operated in parallel while the NS element was off.

Tables M-13, M-14, and M-15 show the number of hours of operation per month in 1986 for the NS, NEW, and SEW antenna elements, respectively. Tables M-16 and M-17 show the number of hours of operation per month in 1987 for the NS and EW antenna elements, respectively. The columns of these tables, labeled with calendar months, provide a breakdown of the MTF operation by antenna current and signal type. Subtotals are given by signal type. A monthly total is also provided. Yearly total hours of operation by signal type and frequency are given in the "Annual Totals" column. The bottom row of the tables gives the number of "changes in operational mode" of the antenna element on a monthly and annual basis.

As in Wisconsin, changes in operational mode in Michigan represent any change in the transmitter facility operating condition. This would include an initial power up and changes in the antenna current, phase (when more than one element is powered), frequency, and modulation scheme. It does not include the powering down of antenna elements. In 1986, the number of changes in operational mode were determined by summing the entries in the MTF log data sheets that satisfied one or more of the above criteria for mode changes. In 1987, the MTF operated primarily on a 15-minute rotational cycle broken into three 5-minute segments to accommodate several measurement crews. This operation pattern is described in Section 4.3. The summarized MTF log tables routinely provided to IITRI show the beginning and ending time of such cycles. Separate entries are not included for each change of antenna elements during this cycle, nor are deviations from the cycle accounted for, such as one field

TABLE M-13. 1986 MTF OPERATIONS SUMMARY: NORTH-SOUTH ANTENNA ELEMENT ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
	Mode: Modulated Signal ^a												
76	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mode: Unmodulated Signal												
76 (4 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	24.43	16.74	10.71	11.49	0.00	0.00	63.37
76 (6 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.11
76 (10 Amps)	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	24.43	16.74	10.82	11.49	0.00	0.00	63.48
Other ^b	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.07</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.07</u>
Totals	0.00	0.00	0.00	0.00	0.00	0.00	24.43	16.74	10.89	11.49	0.00	0.00	63.55
Changes in Operational Mode	0	0	0	0	0	0	290	46	62	120	0	0	518

^aFrequencies listed refer to the center frequency of modulation.

^bDenotes short periods of time at other frequencies or undesignated operation.

TABLE M-14. 1986 MTF OPERATIONS SUMMARY: NORTH EAST-WEST ANTENNA ELEMENT ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
	Mode: <u>Modulated Signal</u> ^a												
76	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mode: <u>Unmodulated Signal</u>												
76 (4 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.11	0.00	0.00	0.00	0.16
76 (6 Amps)	0.00	0.00	0.00	0.00	0.00	18.87	13.80	0.36	2.46	9.15	0.00	0.00	44.64
76 (10 Amps)	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
Subtotals	0.00	0.00	0.00	0.00	0.00	18.87	13.80	0.41	2.57	9.15	0.00	0.00	44.80
Other ^b	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.06</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.06</u>
Totals	0.00	0.00	0.00	0.00	0.00	18.87	13.80	0.41	2.63	9.15	0.00	0.00	44.86
Changes in Operational Mode	0	0	0	0	0	55	20	4	52	166	0	0	297

^aFrequencies listed refer to the center frequency of modulation.

^bDenotes short periods of time at other frequencies or undesignated operation.

TABLE M-15. 1986 MTF OPERATIONS SUMMARY: SOUTH EAST-WEST ANTENNA ELEMENT ONLY
[Hours of Operation]

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
	Mode: Modulated Signal ^a												
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mode: Unmodulated Signal												
76 (4 Amps)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.01	0.00	0.00	0.00	0.05
76 (6 Amps)	0.00	0.00	0.00	0.00	0.00	11.72	0.00	0.00	5.26	5.76	0.00	0.00	22.74
76 (10 Amps)	0.00	0.00	3.87	18.64	6.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.66
Subtotals	0.00	0.00	3.87	18.64	6.15	11.72	0.00	0.04	5.27	5.76	0.00	0.00	51.45
Other ^b	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.03
Totals	0.00	0.00	3.87	18.64	6.15	11.72	0.00	0.04	5.30	5.76	0.00	0.00	51.48
Changes in Operational Mode	0	0	54	78	10	12	0	4	60	156	0	0	374

^aFrequencies listed refer to the center frequency of modulation.

^bDenotes short periods of time at other frequencies or undesignated operation.

TABLE M-16. 1987 MTF OPERATIONS SUMMARY: NORTH-SOUTH ANTENNA ONLY
[Hours of Operation]^a

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
	Mode: <u>Modulated Signal</u> ^b												
76	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mode: <u>Unmodulated Signal</u>												
76 (15 Amps)	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>44.40</u>	<u>27.59</u>	<u>32.40</u>	<u>38.86</u>	<u>33.08</u>	<u>21.79</u>	<u>0.00</u>	<u>198.12</u>
Subtotals	0.00	0.00	0.00	0.00	0.00	44.40	27.59	32.40	38.86	33.08	21.79	0.00	198.12
Other ^c	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.42</u>	<u>0.42</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.84</u>
Totals	0.00	0.00	0.00	0.42	0.42	44.40	27.59	32.40	38.86	33.08	21.79	0.00	198.96
Changes in Operational Mode (estimate)	0	0	0	1	1	533	331	389	466	397	262	0	2380

^aEstimated; see text.

^bFrequencies listed refer to the center frequency of modulation.

^cDenotes short periods of time at other frequencies or undesignated operation.

TABLE M-17. 1987 MTF OPERATIONS SUMMARY: EAST-WEST ANTENNA ONLY
[Hours of Operation]^a

Frequency, Hz	Month												Annual Totals
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	
	Mode: <u>Modulated Signal</u> ^b												
76	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>
Subtotals	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Mode: <u>Unmodulated Signal</u>												
76 (15 Amps)	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>43.95</u>	<u>27.81</u>	<u>32.39</u>	<u>38.61</u>	<u>33.94</u>	<u>21.90</u>	<u>0.00</u>	<u>198.60</u>
Subtotals	0.00	0.00	0.00	0.00	0.00	43.95	27.81	32.39	38.61	33.94	21.90	0.00	198.60
Other ^c	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.25</u>	<u>0.42</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.67</u>
Totals	<u>0.00</u>	<u>0.00</u>	<u>0.00</u>	<u>0.25</u>	<u>0.42</u>	<u>43.95</u>	<u>27.81</u>	<u>32.39</u>	<u>38.61</u>	<u>33.94</u>	<u>21.90</u>	<u>0.00</u>	<u>199.27</u>
Changes in Operational Mode (estimate)	0	0	0	1	1	527	334	389	463	407	263	0	2385

^aEstimated; see text.

^bFrequencies listed refer to the center frequency of modulation.

^cDenotes short periods of time at other frequencies or undesignated operation.

crew controlling the antenna condition for short time periods while other crews are not testing. Thus, the exact number of changes in operational mode and duration of operating time for each antenna element cannot be determined directly from the summarized MTF log data sheets, but were estimated by the procedure described below for 1987.

The total number of mode changes for the two elements was calculated by multiplying the time in hours between the start and finish of the rotational cycling of the antenna elements by 12, since mode changes were on a 5-minute (1/12-hour) basis. The total number of mode changes was then multiplied by 1/3 to give the number of changes for either the NS or EW antenna element. This is because one of three changes that occur in a single 15-minute cycle will involve the NS antenna element, and one of three will involve the EW antenna element.

The monthly operation times for each antenna element that are given in Tables M-16 and M-17 were calculated by multiplying the time period of the rotational cycles by one-third. This is because each element was estimated to have a 33% duty cycle during cyclic operation periods.

The estimates of MTF operating time and changes in operating conditions calculated by the above procedures were judged adequate for general use. However, IITRI can obtain exact, minute-by-minute MTF log data for specific periods on a case-by-case basis as required and requested by the researchers.